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PHOTOGRAPHIC OBSERVATIONS OF HALLEY'S COMET.

E. E. BARNARD.

Since Halley's comet has been bright in the morning skies, but little opportunity has been offered here for securing photographs of it. Though it has been seen a few times, and exposures made on it, the sky in almost every case was too thick and broken with clouds to show anything of value. On two occasions the conditions were favorable. These were the mornings of May 4 and 5, on which dates the sky was clear and fairly transparent. The photographic results were excellent with all the lenses of the Bruce telescope. One of the photographs secured at this time is presented here. This picture was made with the 6-inch portrait lens on May 3, $15^h\ 10^m$ C.S.T. with an exposure of $0^h\ 40^m$. The length of tail shown is six degrees. A photograph with the lantern lens showed a tail 20° long, or about 24 million miles.

On the morning above mentioned, the comet was a beautiful object to the naked eye. The head and nucleus were of the 2nd magnitude and the tail could be traced for about 18° as located on a star chart. On the morning of May 5 the tail, as shown by the photographs, at some 6° or 8° from the head was separated into three principal strands. The photographs with the small lenses would imply an actual length of about 24 million miles.

From the photographs thus far obtained, it would seem that Halley's comet is in no sense a freak comet. Its activity is quiet and orderly. In this respect, and in the photographic action of its light, it is singularly like Daniel's comet *d*, of 1907, which though a fine naked eye object, never showed any phenomena out of the ordinary. Halley's comet therefore does not seem likely to give us very much information as to the physical characteristics of comets in general unless through the aid of the spectroscope. The quiescent condition of the tail and its slow photographic action, may perhaps be explained by the absence of cyanogen in the tail, as shown by the spectrograms taken of the comet by Professor Frost and Mr. Parkhurst.

This element was a strong characteristic of the tail of Morehouse's comet, which was one of the most extraordinary freak comets known. Its apparent feeble light was remarkably strong photographically.

Yerkes Observatory, May 11, 1910.

ON THE PHYSICAL CAUSE WHICH HAS PRODUCED THE SMALL OBLIQUITY OF THE PLANET JUPITER, AND ON THE OBLIQUITY OF THE OTHER PLANETS.*

T. J. J. SEE

In a series of papers recently communicated to the *Astronomische Nachrichten* (Nos. 4308, 4334, 4341-42, 4343, 4351), the writer has treated of some of the leading problems connected with the origin of the solar system for which satisfactory solutions have not heretofore been obtained. As this work gives us an essentially new view of the formation of the planetary system, it is too much to hope that so vast a subject can be adequately discussed in the limited space available in a scientific journal; but it yet seems desirable to outline briefly some of the results which it is hoped may be treated more fully in a forthcoming volume devoted to this important subject.

Before proceeding with the problem of the obliquities of the planets, it seems advisable to notice one criticism of the previous work, in order to make clear the general principles underlying the capture theory. In *Nature*, of July 29, 1909, a reviewer of the paper in *A.N.* 4308 closes his account by asking: "Why, for instance, on the hypothesis of capture are the vast majority of the orbits near the plane of the ecliptic and their motion direct?" This is because our system was formed from a spiral nebula, itself produced by the unsymmetrical meeting of two streams of nebulosity or by the mere gravitational settling of a single nebula of curved and unsymmetrical figure, thus giving a rotating cosmical vortex, or spiral nebula, but without hydrostatic pressure as imagined by Laplace. In Lick Observatory publications, vol. VIII, Plate 38, will be found an illustration of H V. 2 Virginis, a spiral nebula of unsymmetrical figure just beginning to coil up and form a system. What will happen in the later stages of this nebula is suffi-

* From *Astro. Nach.* 4367.

ciently shown in the Lick photographs of the other nebulæ given in this volume. As the mass whirls and condenses under resistance, it will necessarily retain and draw down most of the nebulosity into the principal plane of motion. This is exactly what has given the observed arrangement of the solar system.

All these bodies revolve in the same direction and nearly in a fundamental plane of maximum areas, which was discovered by Laplace in 1784, and by him proved to be invariable. Owing to numerous changes in the physical Universe this invariable plane is the only geometrical element of any system which remains rigorously fixed, whatever be mutual action of the component bodies; and the fundamental plane thus defined cannot be disturbed except by the action of the fixed stars, which are too far away to exert a sensible influence.

In the present series of papers it has been shown that all the attendant bodies of our solar system have been captured,—the planets by the Sun, and the satellites by their several planets,—and that the orbits have since been greatly reduced in size and rounded up under the secular action of the nebular resisting medium formerly pervading the planetary system.

In the paper on the capture of the Moon by the Earth, *A.N.* 4343, I have pointed out the physical cause of the rotations of the planets on their axis, and shown that Planetary Inversion by tidal action does not really take place, as some have heretofore supposed. In a future paper I propose to deal with the difficult question of the secular acceleration of the mean motions of the Sun and Moon, in which some important results have been obtained; but in the present paper I restrict myself to the problems of the obliquities of the planets, the previous solutions of which have been embarassed by many difficulties.

We begin with Jupiter, the greatest of the planets, because here the influence at work has left on the Jovian system so distinct an impress of its mode of operation that there can be no doubt of the correctness of the assigned physical cause. We have found that all the planets have increased greatly in mass, with the lapse of ages, by the capture and absorption of satellites. And it naturally follows that Jupiter above every other planet has augmented his mass at the expense of the smaller bodies of our system.

This is shown by the part this great planet plays in the capture and transformation of the orbits of comets, and by the fact that he has gradually worked the asteroids out of the

regions beyond his orbit, and thrown them into the comparatively stable region within, where they now revolve. That Jupiter has thus transformed the paths of thousands and millions of small bodies once crossing over his orbit, there is not the slightest doubt. Remarkable survivals still existing in our system prove this as clearly as if we had actually witnessed these effects within the historical period covered by exact observations.

On the basis of the phenomena presented by the comets and the asteroids, therefore we may confidently assert that Jupiter has not only transformed the paths of countless small bodies once crossing his orbit, but also that he has greatly built up his own mass by the capture and absorption of small bodies, which for brevity of diction we may speak of as satellites. If we consider the past we see that there was a time when vast quantities of these bodies revolved near Jupiter, in planes passing through the Sun, and having an average motion coincident with the plane of his orbit. The average satellite of this kind when captured and precipitated upon the planet would obviously augment the planet's mass and oblateness, and also tend to bring the Jovian equator into coincidence with the plane of the planet's orbit. Accordingly whatever may have been the original position of the planet's axis, this process of growth has tended to make it more and more nearly perpendicular to the plane of the Jovian orbit about the Sun, which is also the mean position of the swarm of Satellites revolving about the Sun and being gradually captured and absorbed by this giant planet.

Now it is a fact of observation that the axis of Jupiter is inclined from the perpendicular to the plane of his orbit by only about 3°; and this small obliquity tells the story of the capture of vast quantities of satellites so plainly that one cannot mistake its meaning. Moreover, the observed equatorial acceleration of Jupiter, similar to the equatorial accelerations observed in the Sun and Saturn, shows that the process of capture and precipitation of satellites is still going on. The small obliquity of Jupiter is therefore a beautiful illustration of what happens to any planet when the process of capturing satellites has gone far enough; namely, the axis tends to become perpendicular to the plane of the orbit, and the obliquity vanishes.

If we consider the phenomena presented by Saturn, we perceive that his obliquity is less developed than that of Jupiter; for the mass of the former is less than one-third that of the latter, and the distance nearly double. And just as Jupiter

has worked the satellites out of the region beyond his orbit, so also he has both grown on the material thus captured, and at the same time robbed his remoter neighbor of material which otherwise would have augmented the mass of Saturn and diminished the obliquity to a smaller value than it has today.

It is easily shown by calculation that when Jupiter's mass was as small as that of Saturn and his distance as great, his obliquity may have been fully as large as that of Saturn is now.

The moment of momentum of a planet about its axis of rotation is $H = k^2\,\omega\,Ma^2$, where k^2 is the square of the principal radius of gyration, and therefore a constant depending on the law of density, ω the angular velocity of rotation, a the radius, M the mass. For a second planet following the same law of density we have $H' = k^2\,\omega'\,M'\,a'^2$. If new matter be added to the first planet to produce the second, we may imagine the shell thus deposited to be rotating about a different axis, and the two rotations may be compounded geometrically according to the principle of the parallelogram of forces. Now on this hypothesis, with $M' = 3M$, or the matter of the shell equal to $2M$, we have $\omega' > \omega$, $a' > a$, while k^2 remains unchanged, and $H' > 3H$. For the equatorial accelerations observed in the Sun, Jupiter, and Saturn show that as the mass increases by the precipitation of satellites, the angular velocity ω also increases. Two spheres with volumes as 1 to 3, have radii as $1 : \sqrt[3]{3} = 1 : 1.4422496$; and the difference of the moments of momentum about the axes gives that of the shell:

$$H_0 = H' - H = k^2\,[\omega'\,M'\,a'^2 - \omega\,Ma^2] = k^2\,Ma^2\,[3\omega'\,(1.44)^2 - \omega]$$
$$= k^2\,\omega\,Ma^2\left[3\left(\frac{\omega'}{\omega}\right)2.0736 - 1\right]. \qquad (1)$$

Accordingly even if ω' did not exceed ω, $H_0 > 5\,H$, or the moment of momentum of the shell exceeds that of the nucleus by more than 5 to 1.

The increase in the angular velocity ω' over ω, the original angular velocity of the nucleus, depends on the proportion of satellites revolving with the vortex, and accelerating the rotation by falling upon the planet, to those retarding the rotation by falling in all manner of directions. This ratio is not known, but from the proportion of direct to retrograde satellites in the solar system is believed to be about 4/5. Trebling the mass trebles the force of gravity at a fixed distance, and even if the radius be increased from 1 to 1.44, there will still be a large increase in the angular velocity. The problem of the accelera-

tion of the angular velocity probably does not admit of entirely rigorous treatment, but the following process of calculation will give approximately the effect produced. In order to determine the mechanical effect of the downfall of cosmical dust upon the planets rotation we have to evaluate the triple integral:

$$\omega' = \omega \cdot \frac{4}{5} \cdot \frac{1}{2\pi} \cdot \frac{1}{\pi} \int_{a_1}^{a_2} \int_{0}^{\pi} \int_{0}^{2\pi} \frac{M}{a^2} \frac{a^2\, da \sin\theta\, d\theta\, d\Phi}{a \sin\theta} \tag{2}$$

where $dm = a^2\, da \sin\theta\, d\theta\, d\Phi$, and the divisor $a \sin\theta$ gives the torque about the axis.

But as the distribution of material may be taken to be uniform as respects the angle Φ we may immediately integrate relative to this variable; it is also obvious that we may restrict θ to one of the two symmetrical hemispheres. Thus we get:

$$\omega' = \omega \cdot \frac{4}{5} \cdot \frac{2}{\pi} \int_{a_1}^{a_2} \int_{0}^{1/2\pi} \frac{M}{a^5} \frac{a^2\, da \sin\theta\, d\theta}{a \sin\theta} = \omega \frac{16}{15} \cdot \frac{2\pi}{\pi} \int_{a_1}^{a_2} \int_{0}^{1/2\pi} \sigma a^2\, da\, d\theta. \tag{3}$$

When the density σ is taken to be uniform and the matter incompressible this gives

$$\omega' = \omega \cdot \frac{16}{15} \cdot \pi \int_{a_1}^{a_2} a^2\, da = \omega \cdot \frac{16}{15} \cdot \pi \left[\frac{a^3}{3}\right]_1^{1.44} = 2.234\, \omega. \tag{4}$$

Using this value in (1) we obtain finally

$$H_0 = k^2\, \omega\, Ma^2\, [13.8 - 1] = 12.8\, k^2\, \omega\, Ma^2. \tag{5}$$

In this calculation there are several factors to which considerable uncertainty attaches, but it seems certain that the moment of momentum of axial rotation due to the layer including two-thirds of the whole mass could not well be much less than ten times that of the original moment of momentum of axial rotation; so that the original obliquity of 27° would be reduced according to the relations

$$\frac{\sin\beta}{\sin\alpha} = \frac{1}{10}\,, \quad \alpha + \beta = 27°\,; \tag{6}$$

and thus β become less than three degrees. We conclude, therefore, that if Saturn's mass should be trebled by the capture of satellites moving in the plane of his orbit, his obliquity would be practically obliterated, and the new axis of the rotation

would be almost perpendicular to the plane of his orbit about the Sun. Under the circumstances it is clear that Jupiter's obliquity may at one time have been even larger than that of Saturn is now, and yet it would have been almost destroyed in the course of time by the capture of satellites.

In regard to the obliquity of Uranus, we have to judge principally by the planes in which the satellites move, though the planet is found by observation to have an oblateness of between 1:25 and 1:12 (cf. *A.N.* 3992). As the satellites are observed to move sensibly in one plane, and their orbits show no recognized secular displacement, it is to be assumed that they move in the plane of the equator. In *A. N.* 4341-42 we have pointed out that these Uranian satellites are excessively and almost unaccountably near the center of the large closed space about Uranus. It is evident that the major axes have been enormously reduced since these bodies were originally captured. Under the circumstances it is not surprising that in this great reduction of the mean distances the eccentricities have been entirely obliterated.

In connection with this great decrease of the mean distance it is easy to see how satellites have gradually worked down into the plane of the Uranian equator. The effect here is similar to that observed in the case of the inner satellites of Saturn and of the particles composing the ring. Under the action of the oblateness and of the vortex of nebulosity whirling about the planet the revolving particles tend to be drawn into the plane of the equator as the path of least resistance. Satellites revolving about an oblate planet and suffering great reduction in the mean distance, by the action of a resisting medium, thus come finally to revolve nearly in the plane of the equator, as we see also in the case of the inner satellites of the system of Jupiter. For departure from this equatorial plane is resisted more and more, under the effect of oblateness and of the vortex of nebulosity, as the planet is approached; and the wear and tear of the vortex finally leaves the surviving particles adjusted to move exactly in the plane of the equator. This is the origin of the beautiful system of rings about Saturn; and the satellites near the planets everywhere show the same tendency to exact adjustment in the plane of the equator, whether it be in the system of Mars or Uranus. And just as the satellites which now survive about the planets are but a small part of those which once existed, so also the material in the rings of Saturn has been destroyed and renewed many times. This cosmical

dust is within Roche's limit and cannot form a satellite, but the symmetrical arrangement with respect to the equator of Saturn illustrates the action of the oblateness and of the revolving vortex in working the particles into the plane of the equator as the path of descent offering least resistance.

We may therefore take the equator of Uranus to coincide with the plane of the orbits of the satellites. Why then has the obliquity of Uranus remained so large? Simply because the primordial rotation was largely arbitrary and started when the planet was at a great distance from the Sun; and in the later times the supply of satellites coming in to build up the planet's mass has been cut off by the action of Jupiter and Saturn in clearing up the solar system. Jupiter has robbed Saturn of building material, and Saturn has joined with Jupiter in robbing Uranus. This effect is also unmistakably exhibited in the system of Neptune, which has only a single satellite, with zero eccentricity and very small distance compared to the large closed space about the planet, showing that a great interval of time has elapsed since the capture of the satellite took place.

It is thus a remarkable fact clearly demonstrated by surviving phenomena in the solar system, that the inner of the major planets have robbed the outer by gradually cutting off the supply of satellites. This is the significance of the fact that although Uranus and Neptune have larger closed spaces than Jupiter and Saturn (cf. *A.N.* 4341-42), their surviving satellites are concentrated quite near the planets with the outer regions apparently vacant. For these reasons these outer regions may be in fact as vacant as they seem, and search for remoter satellites may prove to be in vain. The failure to find additional satellites about Uranus and Neptune seems to show that no satellites of sensible magnitude have been available for capture by these planets in recent times.

Moreover, since Jupiter has been able to rob Saturn, while Saturn joined him in robbing Uranus; and since Neptune in turn was robbed by all three of the major planets within his own orbit, we perceive in this state of fact an indication that the orbits of the satellites thus cut off from the outer planets were of such considerable eccentricity that they crossed the orbits of the planets next within. This is another answer to Dr. G. W. Hill's question to the present writer as to a reason for thinking that the primitive planetary orbits were necessarily of large eccentricity.

It follows therefore that if Jupiter and Saturn had been removed from our system at an early epoch Uranus would have had a much more extensive system of satellites than he now has, and the mass of Uranus would have grown so much that the obliquity would have been reduced to an insignificant value. But with Jupiter and Saturn cutting off the Uranian supply of material revolving about the Sun, the present high obliquity and the narrow system of satellites concentrated close to the planet has necessarily resulted. And the causes which have operated to prevent the obliteration of the obliquity in the case of Uranus have acted even more powerfully in the case of Neptune.

The arrangement of the obliquities and systems of satellites among the major planets is therefore entirely clear, and it is seen to have been the direct outcome of the available supply of satellites circulating around the Sun. The phenomena still surviving in the solar system thus throw a flood of light upon the state of our system in the remote past, and indicate with certainty that the primordial orbits of the satellites were nearly always sufficiently eccentric to overlap the orbit of the planet next within; otherwise the supply of material for the outer planets would not have been cut off by the inner ones, so as to arrest the development of Uranus and Neptune. The development of Jupiter is typical, that of Saturn fairly normal; while that of Uranus and Neptune is clearly and unmistakably arrested, in spite of the comparatively large masses of these outer planets. And this state of fact can only mean that the supply of satellites was long ago cut off by Jupiter and Saturn; and furthermore that the orbits pursued by the satellites were eccentric enough to have caused them to cross over the orbits of the two inner major planets. From these considerations we get an unexpected light on the development of our solar system. If there are other planets beyond Neptune, they will have suffered still more than the known planets by the cutting off of their supply of building material, and at this late epoch might be quite devoid of attending satellites of any kind.

If we now turn our attention to the inner or terrestrial planets within the orbit of Jupiter, we shall find indications that the same causes have been at work which have operated in the outer parts of the planetary system. The asteroids are the chief survival of the swarm of small bodies formerly traversing the regions of the major planets; but Jupiter has thrown most of them within his own orbit, and almost cut

off the supply of material both for himself and for the other planets beyond. By this same analogy we cannot doubt that the terrestrial planets, Mercury, Venus, the Earth, the Moon (formerly an independent planet), and Mars, at a remoter epoch also crossed over the orbit of Jupiter, and were finally thrown entirely within. Thousands of such planets were engulfed in the Sun, while only those with fairly round orbits escaped absorption. The surviving large eccentricity of the orbit of Mercury is therefore in no sense an exception to the present theory; but the large inclination may have aided this small planet in eluding the influence of Jupiter.

The Moon must have been captured by the Earth after these bodies were well within the orbit of Jupiter and probably even within the present orbit of Mars. The fact that the Moon is not very near the Earth, but at a distance scarcely less than half of that at the time of capture, shows that while the event occurred a long time ago, it was comparatively late in the history of the solar system.

As for the obliquities of the inner planets. we observe that all these globes are small, and therefore they could not have greatly increased their masses by the capture of satellites entering the closed spaces within the Hill surfaces about these bodies. The obliquity of Mars is about 24°.8, that of the Earth 23°.5, while that of Venus is not certainly known, but believed to be small. This is in accord with theory, for a body as small as Mars and more remote than the Earth, other conditions being equal, ought to have a larger obliquity; and in the same way the obliquity of Venus ought to be smaller than that of the Earth.

Accordingly we conclude that throughout the solar system the universal tendency has been to obliterate planetary obliquities, but the deficiency in the supply of material has left the resulting effects on the different planets very unequal though tending everywhere in the same direction of zero obliquity as exhibited in the typical case of the planet Jupiter.

U.S. Naval Observatory,
Mare Island, California, 1909 Aug. 14.

ACCURATE MEASUREMENT OF PHOTOGRAPHS.

EDWARD C. PICKERING.

The accuracy with which positions of the stars may be determined from photographs depends on the accuracy with which the eye estimates the equality of two quantities. The errors from this source are far greater than those of a micrometer of high grade. The magnifying power used does not generally exceed twenty or thirty diameters, since with a high power the individual silver particles are seen, and the photographic image of a star resembles a star cluster, whose center is difficult to estimate. When the images are not circular, owing to imperfect following or distortion due to the image not being in the center of the field of the telescope, these errors are greatly increased, and large systematic errors are introduced, whose amount depends on the position of the star, its brightness and various other causes. Similar errors arise in measuring the intensity of stellar images.

Five cases may be considered, the position of a circular stellar image, the position of a line in the spectrum, the intensity of a stellar image, the intensity of a line in the spectrum, and the intensity of a surface. In each of these cases it appears possible to substitute, for an eye estimate, an automatic method in which the deviation of a galvanometer needle, or its equivalent, replaces the eye. A rigorous determination, free from personal equation, should thus be secured. Distortion of the images might doubtless introduce errors, but they would always be the same for similar images, or for successive measures of the same image.

Four instruments suggest themselves, the thermopile, the bolometer, the radiometer, and the selenium cell. All of these instruments are capable of measuring exceedingly minute radiations, and then require very delicate adjustment; but when, as in the present case, intense radiations are available, their manipulation is comparatively simple.

As the conditions will vary with the different instruments and method of measurement, a single case will first be considered, that of the measurement of the positions of the stars with a bolometer. The two sensitive arms of the bolometer are placed side by side, at right angles to the axis of the screw of the measuring machine, and separated at a distance less than the diameter of the faintest image of a star. An incan-

descent lamp or other source of heat is placed below the photograph and the bolometer immediately above it and close to the film. The bolometer is balanced so that there is no deviation of the galvanometer when the light is in use, and the film, interposed. If now the image of a star is slowly interposed by means of the screw, a portion of the heat is cut off from one arm of the bolometer and the spot of light of the galvanometer darts to one side. It moves to the other side as soon as more heat falls on the other arm. It comes to rest at the zero when the image is so placed, that the silver particles on the edges of the image cut off exactly the same amount of heat from the two arms. A second bolometer placed at right angles to the first serves to measure the other coördinate. If the original images are too small, they may be enlarged by a microscope objective. If an enlarged positive is used, instead of the original negative, the images will be larger, and they will be bright on a dark background. As it is not necessary that the source of light should be constant, daylight may be substituted for the incandescent light.

The conditions for measuring the positions of the lines in the spectrum are much more favorable than in the case of a stellar image. The method is nearly the same, but the length of the sensitive arms may then be nearly equal to the breadth of the spectrum. In this case, many hundreds of silver particles will intercept the heat falling on each arm of the bolometer, and the accidental errors will thus become exceedingly small. If the lines to be measured are broad or hazy, it is only necessary to separate the two arms so that they shall intercept the portions of the edges where the light is varying most rapidly. If the lines are unsymmetrical, sharper on one side than on the other, consistent measures can still be made. They may require a constant correction, but the results for a spectroscopic binary on different nights will still be comparable. This method appears to have especial value for terrestrial spectra where there is plenty of light, since, by increasing the width, the effect of the grain may be almost completely eliminated.

To measure the intensity, or photographic magnitude, a contact print or enlarged negative should be employed. A single broad sensitive arm may be used, so that the entire light transmitted by the image may be received on it. This should be counterbalanced by a second arm which may be moved towards the source of light by a micrometer screw. It is probable that much smaller differences in light can be detected in

this way, than by the best photometric measures, with the advantage that the results will be free from the large systematic errors by which ordinary photometric measures are likely to be affected.

Measures of the intensity of lines in the spectrum would furnish results of great value. This is shown in H.C. 72, and H.A. 48, No. 9. The measures could be made as described in the preceding paragraph, comparing the amount of light transmitted by the images of different dark lines. In the case of bright lines, contact prints or enlargements could be used. The great advantage of this method is that consistent measures could be obtained of lines unlike in appearance.

The measurement of the light transmitted by a surface would be even simpler than in the case of a point or line, and would be made in the same way.

Comparing the different instruments that could be used, minute thermopiles, or selenium cells, could replace the sensitive arms of a bolometer. It might be difficult to make two radiometers small enough to measure the two sides of a line in the spectrum. The latter could however be greatly enlarged by a microscope objective, and in measuring intensities an important advantage would be found in the simplicity of a radiometer.

One of the most important problems to which this method could be applied would be to determine the approach and recession of faint stars by the absorption line of neodymium, described in H.C. 154. For this purpose the bolometer appears to be the best instrument. It is believed by the writer, that the motions of faint stars could thus be measured with an accuracy comparable with that now attained for bright stars by the slit spectroscope. The photographic magnitudes of stars could also be determined with great precision, especially if the method of multiple images described in H.C. 29 was used. The radiometer would probably be the best instrument in this case.

It is evident that the best solution of this problem should be left to the physicist with all the appliances of a physical laboratory at his command, rather than to an astronomer. It is suggested that it would furnish a student in physics with an excellent subject for a graduating thesis. The necessary apparatus could probably be provided, which could then be put into daily use in an astronomical observatory for the long series of routine observations which would be needed to secure results of permanent value.

Harvard College Observatory.
Circular 155. March 21, 1910.

QUALITY OF LIGHT.*

PAUL F. BAUDER.

[Popular Science Lecture, delivered at Witherspoon Hall, Friday evening, November 12, 1909.]

As various new illuminants have been placed upon the commercial market the question has arisen as to the relative value of the light given by them, as an artificial duplicate of daylight. Such a broad use of the term daylight has led to much discussion between the advocates of each artificial light source. It is the purpose of the author to submit results of some investigations upon which an estimate can be formed as to the comparative merits of each of the more common commercial illuminants.

None of the artificial sources of light which the author has investigated gives a quality of light which approximates that of daylight. However, the proper use of those which have been investigated, with a due consideration as to their defects, will tend to assist consumer and producer alike in the improvement of present systems of illumination.

The development of civilized man has taken place beneath the light of the Sun. It would, therefore, appear that the standard of light for all purposes should be sunlight and all of the qualities of this light should apply to the ideal artificial illuminant. This would be the case if man were to labor chiefly out-of-doors as did his predecessors; but the requirements of civilization have been directed towards interior occupation. It is evident for this reason that any variation from an industry undertaken beneath the light of the Sun might require a variation in the character of light to be used whether it be natural or artificial.

Daylight is the only natural light source, while under the heading "artificial illuminants" may be placed all of the light sources which have been in use since the beginning of time.

At best, daylight is greatly variable, but nevertheless it has generally been the light to which artificial sources were referred. It is apparent that this light must have certain fundamental characteristics which make it a standard. A standard of illumination must, however, have certain requirements, the most important of which is constancy. There are so many

* From the Journal of the Franklin Institute March 1910.

varying conditions which affect the light from the Sun that no definite standardization of average daylight has been universally agreed upon by investigators. Those qualities, for a standard unit of illumination, which mark the Sun as the ideal illuminant for the majority of conditions may be classified under the following headings: *Intensity, Color value, Direction of rays, Ability to reveal detail, Adaptability.*

These five qualities will be discussed separately.

INTENSITY OF DAYLIGHT ILLUMINATION.

The Sun is brightest at noon, *i. e.*, the Sun is at its maximum intensity when there is the smallest chance for its direct rays to enter the eye and injure the retina. The eye of man is naturally protected, by the projection of the forehead, from the high intensity of the Sun's light during the larger portion of the day. At sunrise and sunset, however, the rays of light of maximum intensity come in a horizontal direction and are therefore more liable to injure the delicate interior of the eye. The usual presence of mist or fog and the greater absorption due to an additional depth of atmosphere at the horizon decreases the brilliancy and gives to the light a diffusion and color tone, which causes no injurious effect upon the eye. Although the principle of a light source varying to meet natural conditions cannot be applied to artificial illuminants, that of placing the light source above the range of vision, so that the natural construction of the eye may be utilized, is immediately appreciated.

The diffusion and reflection obtained in artificially lighted rooms are far different from the effects obtained with sunlight or daylight. The height of interiors limits man in employing to the best advantage the principle of diffusion in planning artificial illumination.

Actual sunlight which has been referred to is a quantity unknown upon the Earth. The source of sunlight is distant from the surface it illuminates by more than eleven thousand times the diameter of this surface. During the greater portion of the day about fifteen or twenty per cent of the total light received from the Sun is diffused daylight, scattered from finely divided particles suspended in the intervening space between Sun and Earth. If this atmospheric condition were not present, the sky would be dark and spaces to which the light rays were not directly admitted would likewise be dark.

The eye will adapt itself to great changes in the intensity of daylight. A similar relative percentage change in brightness

of artificial light sources as now used would however be prohibitive. On account of the fact that the variation in intensity has but a slight effect upon the ease with which the average person can work under natural light, there must be some characteristic of daylight which under certain conditions will produce a much more marked effect upon the human eye than that previously mentioned. This fact is shown in many industries where the light used must be uniform in color value if not in intensity.

COLOR QUALITY OF DAYLIGHT.

Light is radiant energy which in the form of waves of different lengths affects the nerves composing the retina of the eye. These waves express themselves as different colors. Average daylight or so-called sunlight is a clearer and whiter light than that from any artificial lighting source thus far perfected. When allowed to fall upon a prism, however, it is immediately seen that this white light is composed of seven visible and easily distinguished colors, namely; red, orange, yellow, green, blue, indigo and violet in varying proportions. These colors are the seven fundamental or visible spectral colors which form a part of the total radiation from the Sun. This wave radiation or emission from the Sun affects the human sight only in that portion of the spectrum between the red and blue limits.

The so-called infra-red and ultra-violet extremes of the spectrum, which lie on either side of these values of red and blue, form the larger portion of the radiation from artificial sources and due to their wave lengths they are lost to view. It can readily be shown that the most efficient illuminant would be one in which all of the radiation properly proportioned as to color would occur between the limits of red and blue and therefore would be visible.

Daylight is composed of varying proportions of the seven visible colors. The greatest variation in the quality of daylight may be attributed to the varying percentages of these fundamental colors. In all forms of daylight a certain relationship exists between its different component colors. A relation remaining practically the same under most conditions is that the amount of blue light in nature is maximum while the red is minimum. Such a relation of the fundamental colors can be likewise noted in all growths in which the reds are produced to a less degree while the blues and violets are always apparent. Other primary colors composing daylight vary in amount be-

tween the two limits. A similar statement is true for all forms of light radiation whether natural or artificial; in the latter, however, there does not exist the same proportion of fundamental colors as in any form of daylight.

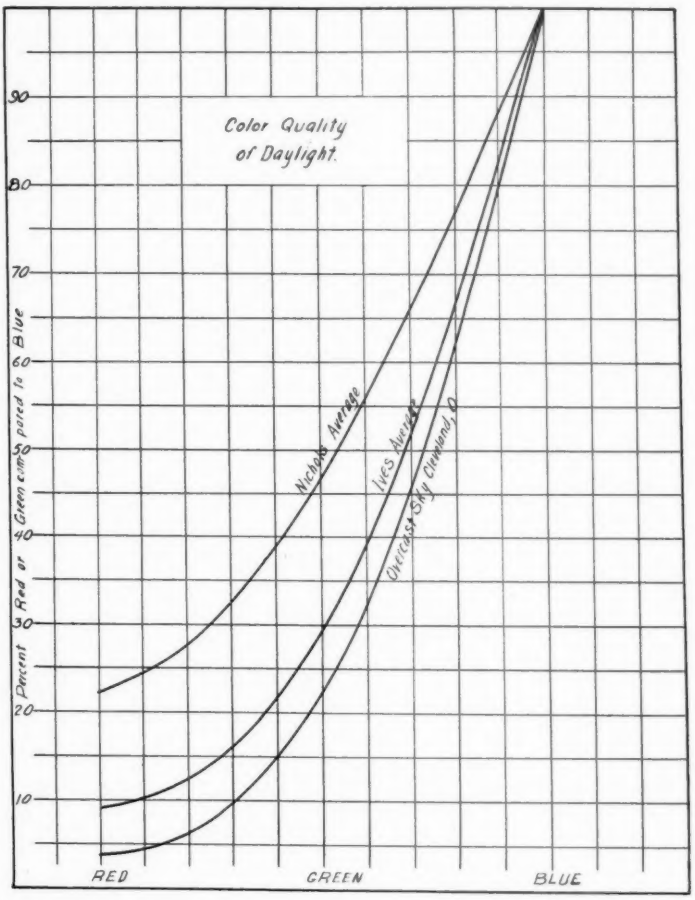


FIGURE 1.

CURVES SHOWING PROPORTIONS OF FUNDAMENTAL COLORS COMPOSING DAYLIGHT.

Reference to the table will enable a fuller understanding of the percentages of the different fundamental colors composing the visible spectrum of daylight to be obtained.

"NICHOL'S" RESULTS FOR PERCENT IN COLOR IN DAYLIGHT—GENERAL AVERAGES.

	Wave lengths in cm.	Lower levels	Higher levels	All levels
Red	725×10^{-4}	5.12	4.14	4.53
Orange	.625	9.09	8.48	8.71
Yellow	.530	13.71	13.37	13.48
Green	.460	19.50	21.62	20.81
Blue	.420	24.46	26.90	26.08
Violet	390×10^{-4}	27.93	25.43	26.45

By exhaustive observation it has been found that any color of light can be duplicated by combining in various quantities three of the primary or spectral colors, namely, red, green and blue. In laboratory practice as well as commercially by the process of trichromatic photography, it is shown that color shades and tones can be correctly reproduced by the proper combination of these three instead of the seven colors. This principle has been embodied in an instrument invented by Mr. H. E. Ives, and called the "Ive's Colorimeter." It is an instrument which gives correct percentages of the three primary colors composing the light from any of the present incandescent light sources. In this apparatus, the three primary colors of light are combined by a so-called color mixing device and allowed to fall on one-half of the field in the instrument the other half being illuminated by the source under test.

By regulating the proportion of the three colors, Dr. H. E. Ives of the bureau of Standards has duplicated the color of average daylight and has likewise made accurate determinations by this method of the proportions of the three colors comprising the light from any artificial sources. His results are given in a paper presented before the Illuminating Engineering Society. Several other investigators, have likewise made measurements which show that the value of blue light composing the average daylight is much in excess of that obtained independently by Dr. Nichols and reduced to same basis as measurements made with the colorimeter.

As previously stated, and as shown by the curves in Fig. 1, it is readily seen that the proportion of the three colors of light composing daylight is so variable that a standard for average daylight would be difficult to obtain. How variable this standard is, may be more readily appreciated if one compares a series of colors as seen in the light of a north window with the same colors as seen at a west window in the light of the late after-

* Transactions Illuminating Engineering Society, May, 1908.

noon Sun. Not only do the natural conditions of the atmosphere produce such great changes in the color value of light, but it must be recognized also that certain conditions affect this quality as much or more than atmospheric changes. The causes of variation in the color of daylight entering any space may be tabulated as follows:

CAUSES INVOLVING THE SKY ALONE.

1. Clear blue sky.
2. Cloudy sky.
3. Overcast sky.
4. Natural conditions due to rain or snow.
5. Natural conditions due to dust or suspended particles.
6. Artificial conditions due to smoke or chemical vapors.

CAUSES INVOLVING THE SURROUNDINGS.

1. Condition and color of surface of ground.
2. Trees, shrubbery or gardens in proximity.
3. Walls of adjacent buildings.
4. Character of windows or openings for the admissiom of light.

The color quality of light which enters any given space may vary in any of the three fundamental colors composing it as much as twenty to thirty per cent, according to changeable conditions of atmosphere and surroundings. For this reason, it can readily be understood that a standard of daylight has not yet been obtained to which artificial illuminants may satisfactorily be compared.

The variations which have been mentioned allow enough changes to take place to make daylight of different qualities unserviceable for some classes of interior work. There are relatively few art studios and shops where articles of delicate color value are sold in which it is possible to make a proper comparison of colors on all occasions. This is due to the many varying conditions affecting the quality of daylight which enters.

It is apparent that more consideration should be given to this characteristic of daylight when it is compared with artificial illumination. Not only should this condition be taken into account in art galleries and other locations where the color of decorations plays an important part in making the sales, but it should also be considered in home interiors, offices and other places where the color plays an important part in the harmonious appearance of surroundings. For instance a man living in a city should be interested in the color which a neighbor paints his house, as it greatly affects the light received through his side windows. Decorative effects are greatly varied

by the condition of the color of the surrounding buildings, etc., to such an extent that when the Sun's light is reflected from a light colored surface such as a snow-covered ground or a white wall of a building, a flat indistinct appearance is given to interior effects. With an exterior ground surface of a soft color tone from which the light is reflected to an interior, the quality of light reflected produces a color effect which greatly improves the interior appearance.

DIRECTION OF RAYS OF LIGHT.

The directional relation of natural light plays a very important part in the general appearance of any surroundings. Maximum daylight is usually received in a plane approaching more nearly the vertical than the horizontal, causing shadows and high lights to appear in correct proportion.

On the other hand an extremely flat effect would be caused by a light with almost complete diffusion, caused in nature both by the presence of suspended dust particles, clouds and many reflections from surrounding objects. A very similar effect is produced when the difference between the lights and shades is too highly accentuated as in the case of objects illuminated by a search light.

It is seen from this that there is a necessity for directing light into such locations that there will be sufficient direct as well as diffused light to make a harmonious shading from high light to shadows without a marked change from one to the other. Shadows may be considered by some as unimportant, because it appears that a person can see almost as well in diffused sunlight, caused by clouds, as in direct sunlight.

On days when there is no direct sunlight there is considerable shadow but there is a less sharp contrast between light and shade because of the gradual character of the change. Were it not that shadows are always present, the work of the architect would not appear very artistic, particularly in exterior work. In interiors the numerous windows acting as light sources cause complex shadow effects, making the problem of illumination with the proper proportion of light and shades more difficult. The adoption, however, of the principle of taking exterior conditions into account, would, no doubt, have a marked effect.

Shadow depends upon direction of light. If the illumination of the lower, or less illuminated portions of an object in daylight were interchanged with upper or more illuminated por-

tions, the object would be almost unrecognizable and constitute a negative picture. Reverse the condition and it at once stands out in detail. With perfect diffusion, however, we would have none of this light and shadow effect, which make an object plainly visible.

ABILITY TO REVEAL DETAIL.

This question of having the proper direction of light in order to make objects visible, invisible, or of revealing detail, has a direct bearing on the question of visual acuity. The color value of light in making possible fine distinctions of detail plays a more or less important part in the physiological effect produced upon the eye. It is found in daylight that a person doing work which requires a proper consideration for fine lines and detail will not depend upon the direct light from the Sun but will in all cases seek a diffused illumination. This may be obtained in a shadow or from a portion of the sky, which is not the brightest. In reading a person will always prefer the light obtained from a window, which is not receiving direct rays of the sunlight unless a shade or curtain of some kind obstructs the direct rays and softens them in intensity and color value. It is true that different eyes are affected differently. Some require more light of one quality than others but in the majority of cases it must be noted that light, for proper purposes of reading or fine distinction, will be within certain limits of intensity and must likewise be of a certain quality and diffusion to allow the least possible direct light to enter the eyes of the observer.

In dealing with the subject of visual acuity or power of revealing detail, with lights of different color value, the effect of large light variation must be considered. Most commercial sources of light due to slight causes vary so greatly in their individual characteristic color quality that it is found necessary, in order to properly designate the best light for given purposes, to turn to the primary colors and note which is best.

Most persons find themselves short-sighted for the light from the blue and violet ends of the spectrum. Patterns, when illuminated by red, green and blue light show that for the power of revealing fine detail with an accompanying ease of sight, the blue and green lights are to be preferred to the red for short distances. The red, on the other hand, is preferred by the majority of persons for revealing details at a greater distance. Keeping this principle in mind, it can readily be seen

what an unsatisfactory effect would be produced if a red or blue-violet light were to be used for general illumination purposes. The important requirement for a light is then to be able to distinguish color values, fine detail, etc., with the proper intensity and direction, whether it be daylight or artificial light.

The qualities of efficiency and steadiness of light production apply more directly to artificial sources of light than to that of daylight. These qualities may be grouped beneath the heading of adaptability, inasmuch as all light should be readily adaptable to meet various requirements.

ADAPTABILITY OF LIGHT.

The light from the Sun was primarily used for purposes of mechanical labor where the necessity of revealing fine detail, obtaining proper color quality, and intensity, were not required to such a great degree as they are at the present time.

On account of the requirements which have been developed in the progress of civilization, daylight has failed to answer for all purposes, due to the fact that our vocations must be pursued at all times without depending upon daylight. For this reason the adaptability of all sources of light, including both natural and artificial, must be given proper consideration.

It has been necessary to use prismatic glass and to adopt an entirely new construction of building and skylights, in order to use natural daylight for such classes of effort as are generally undertaken for manufacturing and industrial purposes. It is true that artificial illuminants must be adapted for more diverse purposes than daylight. They must likewise be directed in such a manner as to meet all interior requirements. Practically all commercial illuminants have been designed with this thought in mind. The ideal light source, on the other hand, must have such qualities of color and ability to reveal detail, such intensity and direction of maximum rays, as to make it capable in all conditions of service to meet certain requirements depending on the conditions surrounding the work for which they were intended.

Artificial Illuminants.—Having discussed the various characteristics of daylight in comparison to artificial light relative to the previously mentioned qualities, we shall make a few direct comparisons. The characteristic qualities of daylight will be compared with the similar qualities of the following illuminants in an endeavor to determine from the standpoint of adaptability which is the best for given conditions:

1. Carbon treated filament lamp.
2. Carbon untreated filament lamp.
3. Gem metalized filament lamp.
4. Tantalum filament lamp.
5. Tungsten filament lamp.
6. Nernst lamp.
7. Enclosed arc.
8. Upright gas arc.
9. Inverted gas arc.

The light flux of all these lamps was so different that no attempt was made to determine their candle-powers. The endeavor was made to obtain the actual effects of the quality of light produced by these sources. The brilliancy of any of them is so far below that of the Sun that the impossibility of obtaining comparisons in intensity between those and the Sun is readily apparent.

In referring to the intensity of the light sources investigated, the advisability of placing a light source of high intrinsic brilliancy a sufficient height above the floor level of any space, in order to benefit by the principles previously noted regarding the Sun, is self-evident. An alternative, likewise possible, is to reduce the intrinsic brilliancy of the source by using glassware of proper design and intensity to increase the diffusion of light and to decrease its brilliancy. By the use of this principle, the necessity of resorting entirely to height in order to produce a sufficient diffusion of light is eliminated.

The question of the color value of given commercial light sources is one which has caused more diverse opinions to be raised than any other quality of artificial illuminants. All artificial light sources have a characteristic quality of color which is apparent from observation. The colors of the illuminants investigated may be tabulated as follows:

	Designation	Color
1.	Carbon (new)	orange-yellow.
2.	Carbon (seasoned)	yellow.
3.	Carbon metalized (new)	pale-yellow.
4.	Carbon metalized (seasoned)	yellow.
5.	Tantalum (new)	yellow-white.
6.	Tantalum (seasoned)	lemon-yellow.
7.	Tungsten (new)	cream-white.
8.	Tungsten (seasoned)	yellow-white.
9.	Nernst lamp (new glower)	pale-lemon-yellow.
10.	Nernst lamp (seasoned glower)	deep-lemon-yellow.
11.	Enclosed Arc (opal outer, clear inner globe)	bluish-white.
12.	Gas Arc, upright (new mantle)	pale-greenish-white.
13.	Gas Arc, upright (seasoned mantle)	pale-greenish-yellow.

The colors of these sources are not readily apparent when used for general illumination purposes. Nevertheless, when a given series of colors is viewed beneath the light from any one

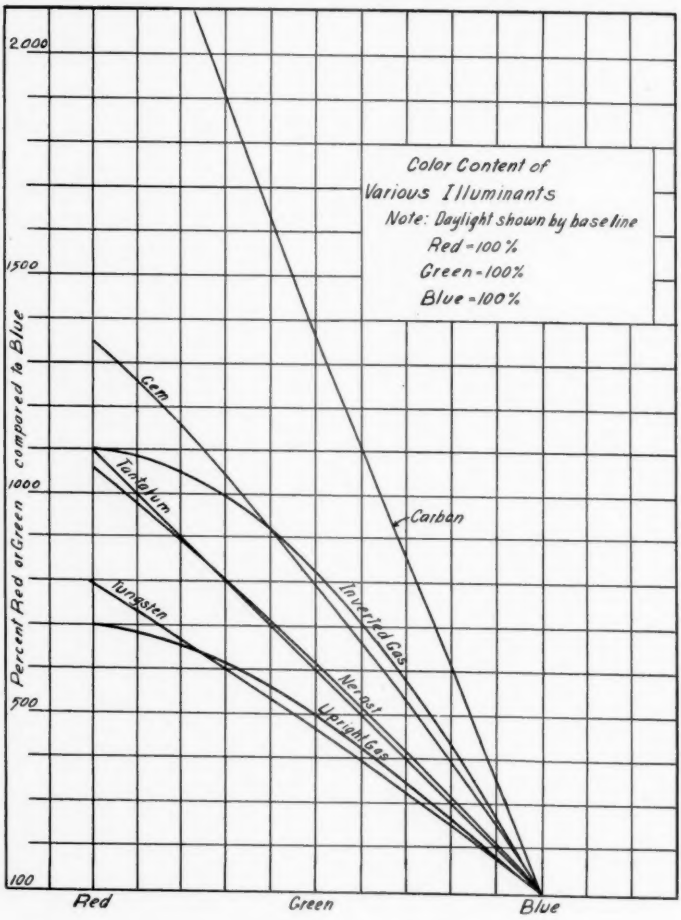


FIGURE 2.

COLOR VALUES OF INVESTIGATED ILLUMINANTS AS OBTAINED BY COLORIMETER

of them which in each case is compared to the similar result under daylight illumination, it is evident that the effects produced vary a great deal from the true color values as seen under daylight illumination.

Color photographs taken under constant conditions of exposure, intensity of illumination, and direction of light upon plates employing the principle of the Lumiere Auto-chrome process of color photography show that none of the artificial light sources obtain results equal to the daylight effect, but the best of illuminants can be selected by the correctness with which they produce the daylight effect.

Another series of photographs, taken under similar conditions, show what a great effect the color quality of light has upon interior decorations, the most delicate of which may be illustrated by the colors of natural flowers.

The colors which compose the given color of light from each of the various sources used for these photographs can be seen from the curves in Figure 2.

The true importance of obtaining the best form of illuminant in order to give the most desirable and attractive results for all classes of service may be observed when a comparison is made between the color effects produced by a carbon and tungsten illumination in comparison with that of daylight. The results show that a surprising advance has been made in the incandescent lamp industry in the endeavor to obtain a type of lighting unit which would cause objects to appear more nearly natural under artificial illumination.

Not only for store lighting but likewise for residence lighting the production of the proper color values and of the proper intensity and direction of light to give a pleasant appearance to interiors should be the general aim for all users of artificial light. Not only from the standpoint of the merchant but likewise from that of the architect, the interior decorator and furnisher, there is necessity for obtaining the best means to advance his efforts in artistic lines. This view should not be limited to mere financial ends for the use of light, but a lasting benefit should be gained by improving the standards for all classes of human effort in art and decoration as well as commercialism.

It has been shown that from the standpoint of direction of light there must be, for satisfactory illumination, not a complete diffusion but a balance giving the proper proportion of light and shade.

In order to obtain a determination of how different interior decorations are affected by the use of light of varied color quality, the effect accentuated to a certain degree may be observed by projecting on a colored curtain the three primary

colors of light—red, green, and blue. If the colors on the curtain and the primary colors of directed light were pure or free from a combination of color pigments forming them, those

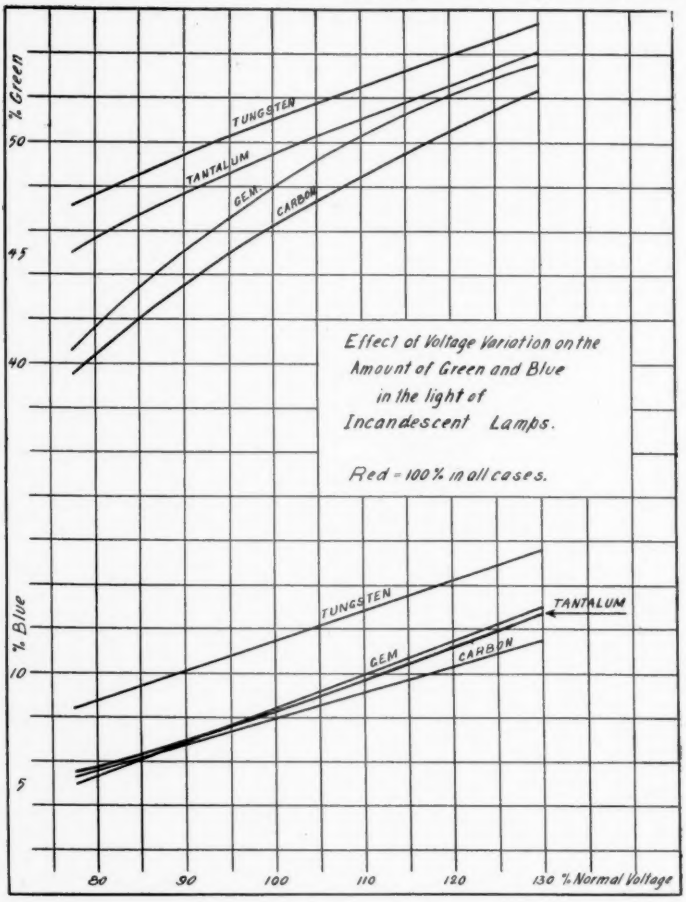


FIGURE 3.

CURVES SHOWING VARIATION OF THE GREEN AND BLUE WITH A VARIATION IN VOLTAGE UPON INCANDESCENT LAMPS.

lines which were not illuminated by a light of a corresponding color quality, would appear black. This is easily appreciated; for the color which is seen, is only the impression received upon the retina of the eye by wave lengths of light which have not been lost by absorption after falling on the colored surface.

The necessity for obtaining a proper proportion of colors forming the light flux emitted from an ideal artificial light source, whether alone or with the aid of glassware, is apparent. This proportion might not be that of daylight, but the colors composing the ideal light source should be such that there would be an equal or equivalent percentage of each of the fundamental colors.

A question has arisen among the users of light as to the actual effect of raising or lowering the voltage impressed upon an incandescent lamp in changing the intensity and especially the color value of such an illuminant. By means of the colorimeter the effect of voltage on green, and the effect of voltage on red (curves Figure 3) were taken with the red 100 per cent in each case, to show what the variation in the green and red fundamental colors would be. The closer approach to the value obtained with the daylight value shown by the base line in each case of the tungsten lamp in comparison to the other incandescent light sources is very marked. Another detail not to be overlooked is that all of the electric incandescent lamps tend more nearly toward the daylight value as the voltage is increased above its normal value.

It is evident that the æsthetic tastes are sometimes appealed to by an incorrect use of illumination, in order to impress the observer with the beauty of surroundings. A more useful result would however be obtained by making the most practical efforts to impress the user of artificial light with the necessity for living and working to his best advantage under conditions requiring the use of artificial light. Owing to the inability of natural light to meet our modern requirements for constancy of intensity, color value, etc., it is obvious that artificial light sources correctly applied must be adopted.

It has been shown that some of the investigated sources are better for one condition of service than are others and it must be concluded that the best artificial illuminant upon the commercial market at present is that which is adaptable to the largest number of classes of service, providing that it maintains a high standard of the afore-mentioned qualities of light.

The importance of obtaining the best possible illumination can be better appreciated when it is considered that, at the present time as never before, there is in the minds of most people a broader comprehension of what constitutes good illumination. The five qualities of the ideal lighting source should not be overlooked, for many thousands of dollars are spent annually on the production of pleasing lighting effects. If these can be improved and the art of illumination placed upon a higher plane, we are effecting material progress.

SKETCH OF THE CAREER OF PROFESSOR C. W. PRITCHETT

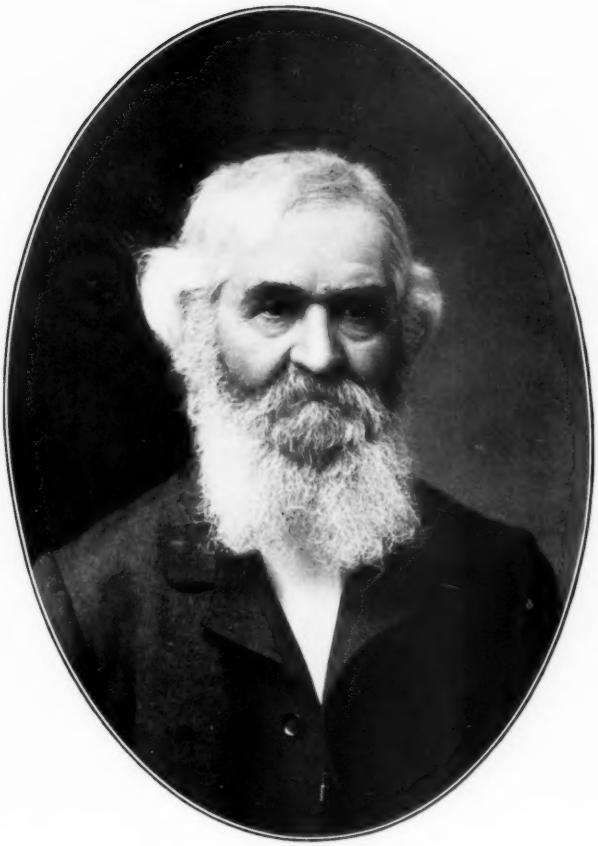
T. J. J. SEE.

By the death of Professor Carr Waller Pritchett, of Missouri, March 19, 1910, America has lost another veteran astronomer who did much to pave the way for the larger scientific progress of our day, while the Mississippi Valley is deprived of a noted educator, whose services extended over a third of a century, and were constantly exerted for the elevation of the standard of American scholarship. The state of Missouri, especially, loses by the death of Professor Pritchett, since he has been identified with her progress since 1844, and thus contributed to her religious and educational advancement for the unprecedented period of sixty-six years.

Professor Pritchett was born in Henry County, Virginia, September 4, 1823, but came to Missouri when a young man of 21, and spent eight months at St. Charles College. Otherwise he was mainly self-educated. In early days he became a clergyman, and held important charges in Pike, Howard, and other Counties of Missouri; so that he went through all the experiences of the pioneers in the growing West, which has now become the dominant power in our national life. In these early days the colleges were supported mainly by individual subscriptions raised among the people, and although financially poor, they had more real spirit of truth-seeking than is to be found in some of the wealthier institutions of today.

The year of 1858-9 was spent in the study of astronomy and mathematics at Harvard College Observatory. Here Professor Pritchett became acquainted with advanced scientific work, and formed friendships with the Bonds, and Benjamin Pierce, and also with Gould, Hall, and Newcomb, who were destined to play so great a part in the development of American Astronomy. From a clergyman and educator he thus became at heart an astronomer, but as the west had as yet no observatories, he returned to his educational work in Missouri and labored to advance the standard of scientific teaching. He aided in organizing Central College at Fayette, Missouri and served as Acting President on two occasions; and in 1866 organized Pritchett College at Glasgow, Missouri; and afterwards, about 1875, secured the establishment of the Morrison Observatory, with a Clark Refracting telescope of 12-inches aperture. Here he long pursued various astronomical researches, but especially

PLATE XIII.



CARR WALLER PRITCHETT,
1823-1910.

the measurement of double stars, and physical observations of the planets. Most of these researches were included in volume I, of the publications of the Morrison Observatory, which appeared in 1885, and is a work of high class.

The most notable of his planetary discoveries was that of the great red spot on Jupiter, which was noted at the Morrison Observatory in July, 1878. It continued to be investigated by Pritchett, Proctor, Barnard, Hough, Struve, and other observers, and has long been a celebrated object of research all over the world.

Professor Pritchett's regular occupation was that of teacher in the college, and he did his work of observation, in addition at spare moments, just as Burnham used to do when a court stenographer in Chicago. The most notable feature of his management of Pritchett College was the high mathematical standard maintained, which gave the College a unique and classic reputation all over Missouri and the west. In this work of teaching Professor Pritchett spent thirty years of the most mature period of his life, and his pupils are to be found all over the country and in Canada and Mexico.

During the period when he was most active in astronomy, Professor Pritchett was in regular correspondence with eminent American and European Astronomers, and his friendships were many and enduring. He also contributed leading articles to reviews and magazines in this country and in Europe, and is well-known by his writings wherever astronomy is cultivated. He was elected a fellow of the Royal Astronomical Society in 1879.

In 1849 he married Miss Betty Susan Smith, of Pike County, Mo., who died in November, 1872. The family consisted of three sons and a daughter. One son lives in Independence, Mo., where the father died; another is a mining engineer in Mexico but the best known is Dr. Henry S. Pritchett, President of the Carnegie Foundation for the advancement of Teaching.

The constancy of Professor Pritchett's friendships is well shown by the sending of his promising son, Henry S. Pritchett, to study with his old friend, Professor Asaph Hall, at Washington, in 1876. Here the younger Pritchett perfected those ideals of science which he has since so well applied to various lines of research, and in public administration while at the head of the U. S. Coast Survey (1897-1900), President of the Massachusetts Institute of Technology (1900-1906), and President of the Carnegie Foundation. There is hardly an astronomer, or

man of science in the country, who does not owe a great deal to Professor Pritchett's distinguished son; and in our grief over the loss of this veteran astronomer at the ripe age of 87, we may be grateful to think that what the pioneer father was unable to accomplish, the more fortunate son is supplying by eminent usefulness in many lines.

It was given unto the elder Pritchett to advance the standard of the church and of education in a leading state of the West and to make valuable and lasting discoveries in astronomy. His head was always among the stars, and his heart filled with tenderness and gentle human sympathy. He took a generous interest in the welfare of young men of science, and in a number of cases helped to start deserving astronomers on larger careers. In all the relations of life he was a true southern gentleman, and left a name that will be greatly honored in the history of Missouri. "Well done, good and faithful servant; thou hast been faithful over a few things, I will make thee ruler over many things: enter thou into the joy of thy Lord."

U. S. Naval Observatory,
Mare Island, California, May 10, 1910.

GRAPHIC SOLAR DISCS.

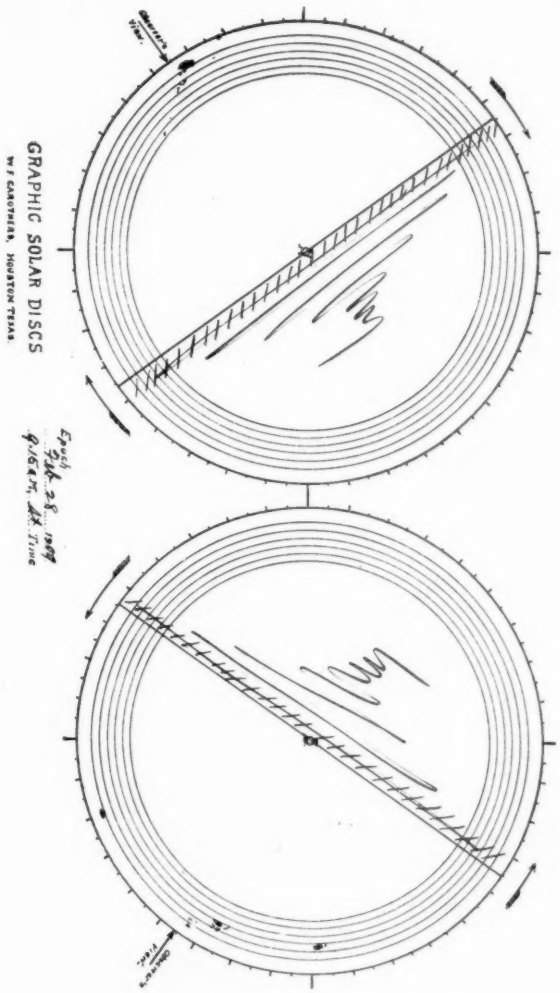
W. F. CAROTHERS.

[Mr. Carothers is an Attorney at Law of Houston, Texas, who is interested in following the changes in the spots on the Sun. He has devised a method of his own for representing the positions of the spots so as to compare them from day to day. It may be that others of our readers will find pleasure in using his method. Ed.]

Solar latitude is marked on the discs by inside circles which of course decrease in diameter towards the poles.

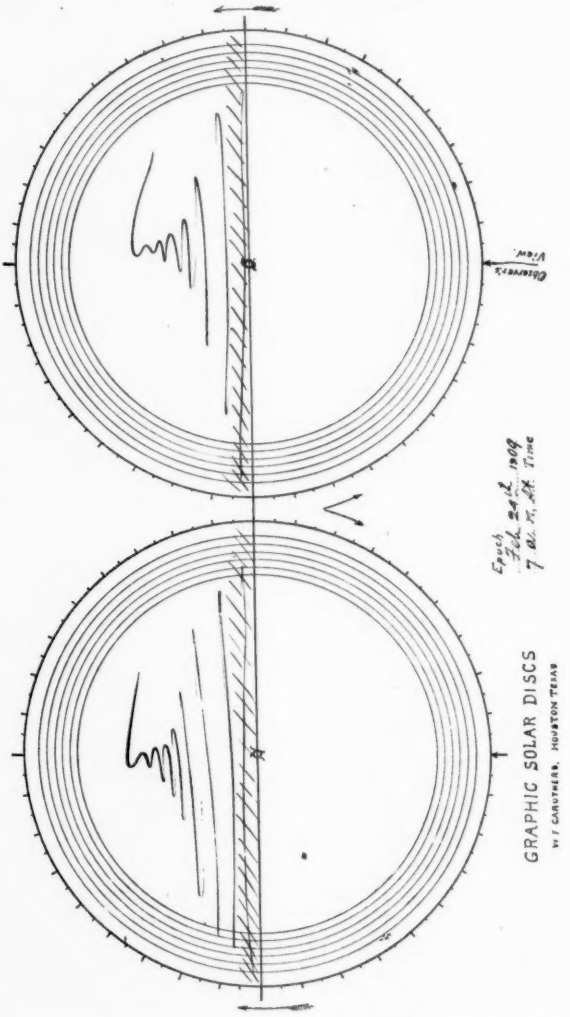
Having the first pair of blank circles thus drawn (I now have them printed), we are ready to plat into them the record for January 1, 1909. The observer's heliocentric longitude for that day corresponds to the longitude on the discs which was his solar meridian at the time of the observation, and, since he could see the Sun's surface for a distance of 90 degrees on

each side of this point, we draw a "terminator" (of the line of sight) through the poles of the discs at right angles to the observer's line of sight, and shade the "back side" of the Sun,



because it is out of view at this time. The recorded markings for that day are then traced into their proper positions of latitude and synodic longitude on the illuminated halves of the

discs, their shapes, sizes and relative positions being represented by an independent mental scale which I find no difficulty in maintaining. It must be remembered, however that this plat-



ting is to present the markings as if seen from the Sun's poles and not from its equator as were the original drawings. I have not found this difficult either and have no doubt any one

would readily catch the hang of it.

A second pair of circles is placed immediately underneath the foregoing pair, for the next observation. At this time the observer has moved around 13.33 degrees per day (on a synodic period of 27 days) since the previous observation, to where his sight illuminates another half of the fixed orb, and thus he continues to move around until he comes back 27 days after starting to view his ORIGINAL SURFACE and compare it with the record now to be entered.

The effect of this successive, progressive illumination of a stationary disc has been marvelous to my eyes. Where before my year's record was all a mass of interminable and incomprehensible data, it is now spread out before me in the most orderly and obedient fashion, literally eloquent with the lessons we wish to learn. At my leisure, now, I may ponder these revelations and expect to learn something new from them time and again. Since this method locates a marking at its same place each revolution of the Sun, it is easy to identify it and to note the changes which have occurred (and this is what we wish to know about them.) The location, origin, progress, changes, duration, disappearance and re-appearance of spots and faculæ are hereby made matters for the simplest observation and most comprehensive study.

While I have no clock work and micrometer and have to make all my measurements with the eye, yet I see no reason why these discs are not capable of reproducing the most scientifically accurate observations.

At any rate its fine for an amateur.

I began my observations of Sun-spots on January 1, 1909 with a splendid little 2⅝-inch refractor and have kept a faithful amateur's record ever since (missing one month in the summer) the record for the eleven months consisting of 73 observations, illustrated with drawings every few days and otherwise made up of notes. For the drawings I used 3½-inch circles and simply platted the scene as it looked through the telescope, noting the diurnal westerly drift. During the year I worked out, independently, the different effects of the various telescopic eye-pieces, as well as the effect upon the solar face of (1) the observers terrestrial latitude, (2) his heliocentric longitude in view of the solar inclination, and (3) the observers daily rotation (morning, noon and afternoon observations, etc.) so that towards the end of the year I could determine as nearly as it may be done with the eye, the position of the solar

equator and markings.

So much for my daily records.

But when I wished to sumarize the results of the observations I met with difficulty. I tried in several ways to tabulate the work with no success and finally hit upon the method here outlined.

The principle involved, is to fix the Sun stationary and as if seen from its poles by the student and represent the recording observer (as distinguished from the tabulating student) as passing around the Sun in the retrograde direction, illuminating the observers side of him as he goes.

Two companion circles are used for each recorded observation, one to represent the northern and the other the southern solar hemispheres, their circumferences representing the equator and the centers the poles. The circle to the left I use to represent the northern and the one to the right the southern hemisphere—as if the Sun were divided at his equator, hinged at the right and the southern hemisphere opened out to view like the underlid of a watch.

Around the rim of these circles degrees are marked off to aid in locating the solar meridian (which is of course the view point of the terrestrial observer.) These degree marks also assist in platting in the solar markings, although they must not be confused with actual solar longitude.

NEW DOUBLE STARS.

E. D. ROE, JR.

The following new double stars have been recently found and in most cases measured with the 6½-inch Clark refractor and Gaertner micrometer of my observatory. The same notation is used which was introduced in *A. N.* 4338, and afterwards employed in *A. N.* 4381 and *A. J.* 611, where lists of new double stars found by the writer are given. The positions of the pairs are *Durchmusterung* positions corrected for precession to 1910. I am under great obligation to Professor Burnham for assistance in identifying the SD pairs ρ 28 and ρ 30 as well as the BD pairs ρ 29 and ρ 34, and to Professor Fox for confirming the duplicity of ρ 34 and for his measure of it.

ρ 25 BD + 12° 1474 $7^h\ 10^m19^s$, + 12° 30′ (10^m,11^m)
Found 4 March, 1910.

1910.177	358°.7	3″.14
1910.190	360 .5	3 .11
1910.183	359 .6	3 .12

ρ 26 $7^h\ 10^m\ 20^s$, —15° 10′ (9^m, 11^m, 10^m)
Found 3 March, 1910. 22ˢ.5 preceding and 9′.4 north of β G. C. 3934, β 575.

	A and B	
1910.196	118°.8	8″.0
	A and C	
1910 196	50°.2	41″.29

ρ 27 $7^h\ 10^m\ 42^s$, — 0° 24′ (9^m, 9.8^m)
Found 1 April, 1910. 29^s.8 preceding and 4′ north of G. C. 3938, Howe 17.

1910.253	50°.0	9″.08
.280	50 .3	8 .73
1910.266	50 .1	8. 90

A distant comes 10^m.5 at 43°.5, 54″; another 11^m at about 129°, 120″.

ρ 28 SD (15°) 1736 $7^h\ 12^m\ 31^s$, — 15° 49′ (9^m, 9^m)
Found 2 March, 1910.

1910 168	29°.5	4″.04
.171	29 .9	4 .17
.174	29 .6	3 .96
1910.171	29 .7	4 .06

ρ 29 BD — 1° 1680 (9^m.5) $7^h\ 18^m\ 4^s$, — 2° 5′
Found 25 March, 1910.

1910.236	211°.7	10″.05
.253	211 .4	10 .38
.256	211 .4	10 .11
.270	211 .3	10 .49
1910.254	211 .5	10 .26

ρ 30 SD (15°) 1932 $7^h\ 32^m\ 48^s$, — 15° 15′ (9^m, 10^m)
Found 5 March, 1910.

1910.177	281°.8	7″.29
.210	280 .2	7 .25
1910.193	281 .0	7 .27

Two small stars south and one faint one north preceding, all at about 65″ distance.

ρ 31 $7^h\ 46^m$, $-3°\ 4'$ (rough place) ($9^m.7$, 10^m)
Found 1 April, 1910.

1910.253	115°.5	7″	(estimate)

ρ 32 BD + 12° 1737 $7^h\ 55^m\ 22^s$, 11° 53′ ($9^m.5$, 10^m)
Found 5 March, 1910.

1910.177	287°.2	
.220	288 .4	8″.94
.230	288 .2	8 .85
1910.209	287 .9	8. 89

ρ 33 $8^h\ 45^m\ 11^s$, 6° 57′ (10^m, 11^m)

Found 1 April,1910. $12^s.6$ preceding and 3′.6 north of a $7^m.7$ star which is BD + 11°2037

1910.256	86°.6	4″.50

ρ 34 BD + 11°1930 8^h 47, 11° 39′
Found 23 March, 1910.

This proved to be a very trying pair for the 6½-inch. I think because I could not get proper atmospheric conditions. I measured it on one night and made

1910.230	347°.3	2″.88

I looked at it as often as possible and eventually I was not sure whether it was double. I finally referred it to Professor Fox who kindly observed it with the 18¼-inch and confirmed its duplicity and sent me the following measures of it.

1910.337	345°.9	3″.68	9.8 — 11.3
.340	348 .8	3 .68	
.351	349 .0	3 .31	9.4 — 11.0
1910.343	347 .9	3. 56	9.6 — 11.1 Fox.

ρ 35 BD + 14° 2059 $9^h\ 11^m\ 35^s$, 14° 45′ (9^m, 10^m)
Found 8 April 1910.

1910.270	256°	8″	(estimate)

Syracuse University, May 11, 1910.

PLATE XIV.

EDMUND HALLEY,

[From Chambers' "The Story of the Comets."]

THE STORY OF HALLEY AND HIS COMET.

RALPH E. WILSON.

Owing to the great popular interest in the appearance of Halley's comet at the present time, it seems fitting that the history of the comet should be reviewed and some of the interesting facts of the present appearance presented to our readers. Those who wish to read more about this celestial wanderer are referred to former articles in POPULAR ASTRONOMY.

May 1908, The Next Apparition of Halley's Comet.—H. C. WILSON.
June-July 1908, The Story of Halley's Comet.—JOHN CANDEE DEAN.
March 1910, The Apparent Path of Halley's Comet in the Sky.—WM. F. RIGGE.
April 1910, An Historical Examination of the Connection of Calixtus III with Halley's Comet.—WM. F. RIGGE.
May 1910, The Real and Apparent Positions of Halley's Comet During its Period of Greatest Importance.—JOSEPH WILZEWSKI.

By way of introduction a few words with regard to Halley the man will not be out of place. Edmund Halley was born October 29, 1656. His father was a wealthy soap boiler and was able to give his son a good education, first at St. Paul's School and later at Queens College, Oxford. Though he was excellent in all his studies, his superiority was most conspicuous in mathematical studies and it is evident that from the first his favorite pursuit was astronomy. In 1676 when he was but twenty years of age, Halley published a paper on the orbits of planets, which at once placed him among the foremost of theoretical astronomers. In the same year, seeing that the progress of exact astronomy must depend largely upon the determinations of the positions of the stars as accurately as possible, and that Hevelius at Danzig and Flamsteed at Greenwich were already engaged in work of this character in the Northern Hemisphere, he set off for St Helena to work in the virgin field of the Southern Hemisphere. Owing to the poor climatic conditions which he met, he was able to publish on his return the positions of but 341 stars. This catalogue however was in itself a valuable addition to exact star positions and is remarkable in that it was the first catalogue based on telescopic observation.

After his return to England in 1678, Halley was made a Master of Arts at Oxford and later elected a Fellow of the Royal Society. Within a year of this election, he was chosen

by the Society to represent them in a discussion which had arisen with Hevelius, as to the relative accuracy of star positions determined with the naked eye aided by sights and with the crude telescope of the time.

Halley was made Savilian Professor at Oxford in 1703 and later served as secretary of the Royal Society. In 1721 he succeeded Flamsteed as Astronomer Royal. This position he held up to the time of his death in 1742 when he was 85 years of age.

Among the early important work published by Halley, is a paper on the variation of the magnetic compass, as the departure of the needle from the true north is called, a paper which was far in advance of his time, as the subject was not taken up again until 1811. He was the first to call attention to the secular acceleration of the Moon's mean motion and to the importance of transits of Venus as a means of ascertaining the distance of the Sun. In 1718 he introduced the idea of proper motions of the fixed stars by calling attention to the fact that three well-known stars, Sirius, Procyon and Arcturus had changed their angular distance from the ecliptic since Greek times. He called attention to the irregularities in the motions of Jupiter and Saturn and assigned the causes correctly to their mutual perturbations. By means of a long series of observations of the Moon and planets both before and after his appointment as Royal Astronomer, Halley was able to make some improvements in the tables of these bodies. Though these tables were never worked out to Halley's satisfaction nor published until ten years after his death, they at once became and for some time remained the Standard tables of the lunar and planetary motions.

Probably the greatest service which Halley ever rendered to human knowledge was the part he took in securing the publication of Newton's "Principia." This great work would in all probability never have been published had not Halley made a visit to Newton and been shown some of his investigations. Halley perceived the tremendous importance of Newtons researches and attempted to have them published by the Royal Society. When, on account of lack of funds, they were unable to do this, Halley, himself, though at the time in straightened circumstances, assumed all the responsibility and expense of the publication.

It is worthy of notice that the work upon which Halley's fame in largest measure rests, must have appeared during his

lifetime as of little value. The first pair of transits of Venus, from which he had shown how to deduce the distance of the Sun, took place after he had been dead nineteen years and the comet, which bears his name and the reappearance of which he had predicted, did not return until seventeen years after his death. Yet it is to these two pieces of work and to the latter in particular that Halley owes his fame.

The discovery of the periodicity of the comet now known as Halley's was a direct result of Halley's association with Newton, so we see that, while Halley did so much for Newton, he also received a great deal from the contact with Newton and with his wonderful investigations.

Newton had explained the movements of the planets and had shown how the orbits of comets could be obtained from three observations. The comet orbits were all supposed to be parabolic. Were the orbit elliptical it would have to be so elongated that the small part, within which the comet is both near enough and bright enough to be seen from the Earth, would be indistinguishable from a parabola. Halley computed the orbits of twenty-four of the brighter comets which had appeared between the years 1337 and 1698. Among these he noticed three, which followed tracks so closely resembling each other that he was led to conclude that the so-called three comets were only three reappearances of the same body. Further examinations of ancient records showed comets with similar orbits appearing at intervals of 75 or 76 years for four centuries back. The periodicity of the comet seemed to be fairly well established. The question of the next reappearance remained as a test of the periodicity and, after a great deal of calculation, in which he took into consideration only the retarding effect of Jupiter, Halley assigned, as the time of reappearance, the latter part of 1758 or the beginning of 1759. The discovery of the comet on Christmas night 1758 bore testimony to the remarkable sagacity of the man who had made this prediction 53 years before.

With the knowledge of the periodicity of the comet, there remained the study of its identity with certain of the comets of earlier times. Halley himself carried the identification back to 1305. Later astronomers, using more modern methods for computing the perturbations produced by the planets, have been able to carry the probable identification back to the third century before Christ. The basis for the study of all appearances up to the fourteenth century has been the records

of the Chinese. From these records an idea of the path of the comet has been obtained and the comparison of this path with that computed from modern observations has in many cases revealed the identity of the comet with that of Halley.

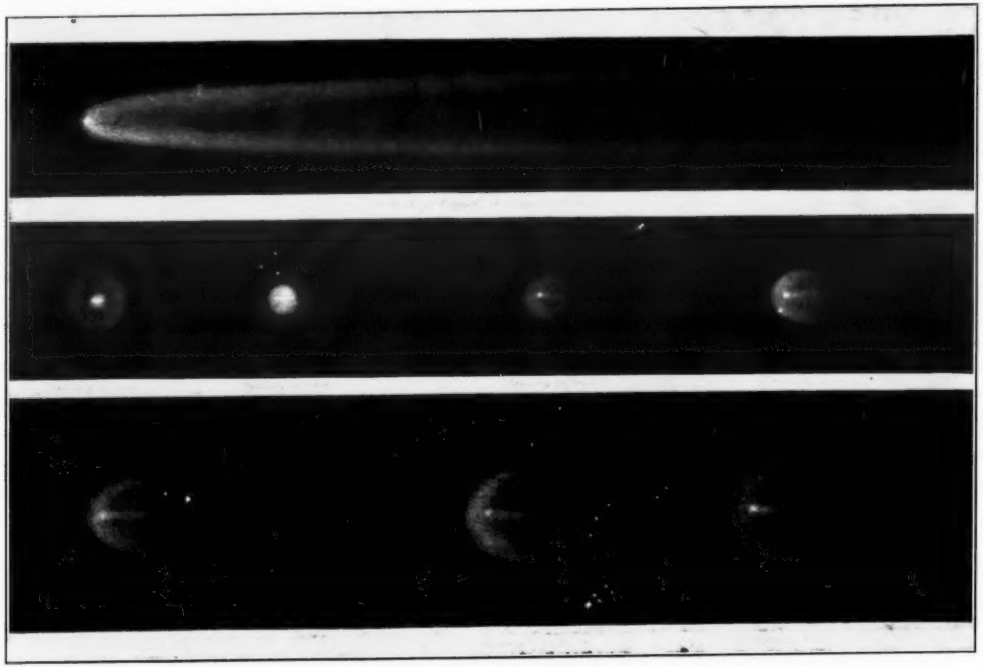
The earliest record of a comet, which may have been that of Halley, is given by the Chinese in 240 B. C. There is no evidence, beyond the time of its appearance, to establish its identity. There are no comets recorded in 163 B. C. In the "Theatrum Cometicum" by Lubienietz, there is mention of a bright comet in 87 B. C. In this year the Chinese record a comet visible during August. Modern calculations indicate August or September, as the time of perihelion passage at this appearance, so that there is probability that this was Halley's comet. From a comparison of the elements, there is very satisfactory evidence that the comet of 11 B. C., the path of which was carefully recorded by the Chinese, was Halley's comet.

Cowell and Crommelin of the Greenwich Observatory have definitely confirmed Hinds identification of the comet of 66 A.D., as that of Halley. This comet was supposed to be the procursor of the destruction of Jerusalem. The comets of 141 and 218 were certainly returns of Halley's comet. In 218 it was considered as the herald of the death of Caracalla. The identity of the comets of 295 and 373 are by no means as certain. The comet of 295 was observed in China but there is little evidence beyond the time of appearance upon which to base an identification. In 373 the Chinese record a comet in Ophiuchus in October. This would fit in with the position of Halley's comet if the perihelion passage took place early in November.

The comet of 451 was shown by Laugier to be that of Halley. It appeared about the time of the battle of Châlons, when the Roman general Aetius defeated Attila, the leader of the Huns who had been ravaging central Europe. There was a comet in 530 but so few circumstances of its appearance are recorded that we cannot say whether it was or was not that of Halley. A comet observed by the Chinese in 607 has been identified as Halley's by Cowell and Crommelin, in contradiction to Hinds identification of one of 608. The observations of 607 are undependable. There seem to have been at least two and possibly four comets during that year and Cowell and Crommelin, although certain of Hind's error, were not satisfied with their own identification.

The appearances of the comet in 684, 760 and 837 have been

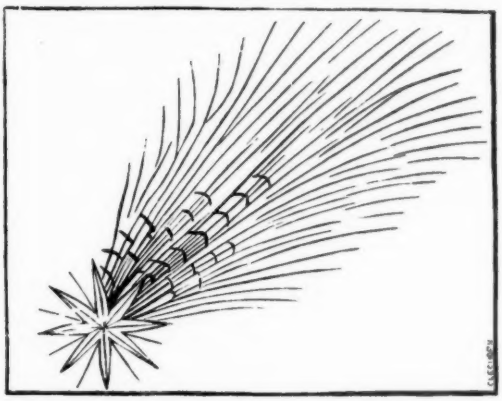
PLATE XV.



HALLEY'S COMET, 1835-36.

[Drawn by C. P. Smyth. From Chambers' "The Story of the Comets."]

definitely established by the recent researches of Cowell and Crommelin. The comet of 760 is described as "a great beam of light and very brilliant, being visible for about 30 days, first in the east and then in the west." The year 837 must have been a wonderful year for naked-eye comets, for the Chinese



HALLEY'S COMET, 684 (*From the Nuremberg Chronicle*)
CHAMBERS' "THE STORY OF THE COMETS"

records imply that there were four that year, in February, April, June and September. The first was identified as that of Halley.

The identity of Halley's comet in 912 is uncertain. Cowell and Crommelin differ four months from Hind in the date of perihelion passage. They state that the computed position of Halley cannot be certainly identified with any comet observed in this year. This is the last date at which there is any uncertainty as to the identification of Halley's comet. The elements of the orbits from 989 to the present day give direct evidence as to the identity of the comet.

The appearance of the comet in 1066 was remarkable. Zonares, the Greek historian, describes it as "large as the full Moon, at first without a tail on the appearance of which it diminished in size." The Chinese say that it was visible for 67 days after which "the star, the vapor and the comet all disappeared. At this appearance the comet was supposed to foretell the defeat and death of Harold in the Norman conquest and a depiction of the terror and amazement of the people has been handed down to posterity in the famous Bayeux Tapestry, which is supposed to have been made by Queen Matilda, the wife of William the Conqueror.

At the 1145 appearance, the European and Chinese chroniclers record a tail about 10° long. In 1222 the comet appeared in Bootes as a star of the first magnitude, with a tail 30 cubits long. It was visible for two months. In 1301 its appearance is mentioned by nearly all the historians of the period. It was seen as far north as Iceland and exhibited a bright and extensive tail which stretched across a considerable part of the heavens. Although the reappearance in 1378 was observed in

HALLEY'S COMET, 1066. (*From the Bayeux Tapestry*)
CHAMBERS, "THE STORY OF THE COMETS."

both Europe and China, it does not seem to have attracted as much attention by its brilliancy as in either former or later appearances. In 1456, the comet was described by the Chinese as having a tail 60° long, shaped like that of a peacock, and a head which was at one time round and the size of a bulls eye.

The three following appearances in the years 1531, 1607 and 1682, led Halley to discover the periodicity of the comet. The appearances in 1531 and 1607 do not seem to have been especially remarkable. The comet was not especially bright and the tail only about 7° in length. In 1682 the comet was discovered by Flamsteed, in August. At the time of the discovery the head was about 2′ in diameter and the tail 6° long. Later on in August, it shone as a second magnitude star and had a curved tail about 10° long. During the latter part of August it was still bright, with a tail from 12° to 16° long and could be seen all night. On September 11 the head was very diffuse and the nucleus not noticeable. Most noteworthy in its appearance was the existence of a brilliant ray or sector thrown out from

the nucleus into the tail. This phenomena was very noticeable again in 1835.

According to the prediction of Halley, the comet was rediscovered with a telescope of 8-foot focal length, December 25, 1758, by a peasant named Palitzsch, living near Dresden. The comet was visible for five months and on May 5 had a tail 47° long. The time for perihelion passage at this appearance was computed beforehand by Clairaut, Lalande and Madame Lepaute and was announced to take place within a month of April 13. It actually occurred on May 12, so that Clariaut's prediction was true.

Prior to the return in 1835 Damoiseau, Pontecoulant and Rosenberger of Halle calculated the position and time of perihelion passage. The last named carried out the most complete computations, taking into account not only the influence of Jupiter, Saturn and Uranus but also that of Venus, the Earth and Mars. The comet was rediscovered on August 6 by Dumouchel, director of the Collegio Romana Observatory at Rome. At the time it was faint and barely discernible. Because of unfavorable weather conditions it was not seen again until the 21st, when W. Struve found it in the great telescope at Dorpat. It became visible to the naked eye September 23, and a tail was seen on the 24th. During October the comet was conspicuous, with a tail from 20° to 30° in length. At this time an extraordinary phenomenon was noticed, in the shape of a luminous sector, issuing from the nucleus and shooting into the coma. The light from this sector was stronger and of different aspect from that in the nucleus or coma. During perihelion passage the comet lost its tail and appeared as a star of the third magnitude. A nucleus surrounded by a halo was visible until January 28, when the halo disappeared and only the nucleus remained. During the next three months this became elongated, increasing in size and decreasing in brightness, until it was finally lost in the surrounding darkness.

Pontecoulant, who predicted the circumstances of the return in 1835, predicted a return in 1910 but did not undertake the task of computing the details. This work was done by the Greenwich astronomers, Cowell and Crommelin. The disturbing actions of all the planets were taken into account and perihelion was first set for April 8, 1910. This was later corrected to April 18. The actual perihelion passage took place April 19, so that the computations may be regarded as extremely accurate.

Throughout the year 1909, photographs were taken of the regions in which the comet was expected to appear. On September 11 it was photographed by Wolf at Heidelberg and on the 12th, 13th and 14, with the Crossley reflector at Lick Observatory. On September 15, it was seen visually by Burnham at the Yerkes Observatory and shortly after this, by many others. On September 24, Barnard at Yerkes measured the diameter of the comet as 11″. There was no definite boundary but in the center there was an indefinite condensation almost amounting to a small nucleus. The magnitude was estimated as 15th. During October it became a little brighter, being about the 14th magnitude on the 17th. Its diameter increased to 15″ and the bright center became a little more definite. During the early part of November it was still so faint as to be visible in only the larger telescopes. Photographs taken at this time show clearly a star-like nucleus. On November 18 a faint tail, 6′ long and about 1.′2 wide was discerned. It was slightly curved and looked like the miniature of a great comet.

From November to February the comet showed remarkable variations in light. On November 22, after it had been for some time between the 12th and 13th magnitudes. it suddenly brightened up to the 10th. On the 30th it was 11 magnitude and during December varied between 10.4 and 12.5. During January and February, 1910, variations were observed but, as the comet was rapidly becoming brighter, they were not as noticeable as in the early months.

On November 30 the diameter of the coma was 41″ and of the nucleus, 7″. On December 18 the coma was nearly round and about 1′ in diameter; the tail was about 15′ long. On January 29 Wolf photographed a coma 2¼′ in diameter, with a definite nucleus and a tail 20′ long. On February 11, the same man saw the comet with the naked eye. After this time it did not get much brighter and although photographs were taken as late as the second week in March, no noteworthy developments were noticed. During the latter part of March and the first part of April the comet was behind the Sun.

On April 18 the comet was photographed at the Lowell Observatory. The tail was 9° long and noticeably bent about 4° from the head. During the latter part of April, variations in the shape of the tail, from day to day, were especially noticeable. On the 25th it was divided into three narrow streamers with a central branch and two symmetrical side branches; on the 26th it was narrow and straight; on the 27th it was

branched again as on the 25th. On the 30th the northern edge was nebulous and indefinite, while the southern was bright and well defined. The tail near the head was composed of numerous well-defined streamers.

The sector, mentioned by Hevelius in 1682 and Smyth in 1835, was recalled by Morehouse, at Drake University, on May 1. He says, "This morning at 4 o'clock Halley's comet had a short bright tail projecting toward the Sun. Two bright rays bordered the outer part of this sector, forming an angle within the nucleus of about 86°. The south preceding one was much the brighter."

On May 6, the comet was about 2nd magnitude, although the nucleus was nearly a magnitude fainter than on April 27. The tail was quite long and bifurcated.

It was not until the second week in May that the comet began to fulfil, in size and brilliance, the expectations of astronomers and then it was so nearly between the Earth and the Sun that photographs of the coma could not be taken. On May 15, Barnard, at Yerkes, traced the tail beyond the star θ Pegasi, which would correspond to a length of about 50°. At about three-fourths of its length from the head it was between 3° and 4° broad and seemed to be straight. The nucleus was many times fainter than Venus.

On May 17th Rev. J. H. Metcalf of Taunton, Mass., traced the tail to 71 Aquila, giving a length of 70°. He estimated the breadth of the tail at the end as 8° or 9°.

On the morning of May 18, the day on which the comet was scheduled to pass between the Earth and the Sun, the tail was a magnificent object. It was traced, at this observatory, to a point just south of θ Aquilæ. About 75° of tail was visible above the horizon and there was at least 30° below it, so that the tail must have been about 105° long. The part visible above the horizon seemed to be almost straight.

On the evening of the 18th, the head of the comet passed between the Earth and the Sun but the suppositions that the Earth had passed through the tail were shattered the next day, when reports were received from both the Yerkes and Lick observatories indicating that the tail of the comet was still visible in the east on the morning of the 19th, when it should have been on the other side of the Earth. This may be explained by supposing that the tail had a much greater curvature than astronomers had inferred from earlier views of it. In this case the Earth passed through the plane of the comets

orbit before the tail reached us and the encounter was avoided. At the time of the transit of the head across the Sun's disc, no phenomenon which may possibly have been produced by the influence of the comet, was visible, except an aurora in the northern part of the sky.

On the evening of May 20, the head of the comet was visible to the naked eye in the west and measures of its position were made at this observatory. The moonlight will obliterate the tail until the 25 or 26th. At that time we may be able to see the tail, although the comet will in the meantime have receded so rapidly from the Earth, that it will probably not be very conspicuous.

Goodsell Observatory, May 21, 1910.

PLANET NOTES FOR JULY AND AUGUST, 1910.

Mercury will be at Superior conjunction July 19 and will not therefore be visible during that month nor the early part of August. It will be at greatest elongation from the Sun on August 30, and near that date ought to be visible for an hour after sunset.

Venus will be a morning star throughout the two months and during that time it will travel out of Taurus, through Gemini and Cancer, and into Leo. It will be in conjunction with the Moon on July 3 and August 2, and with Neptune on August 10.

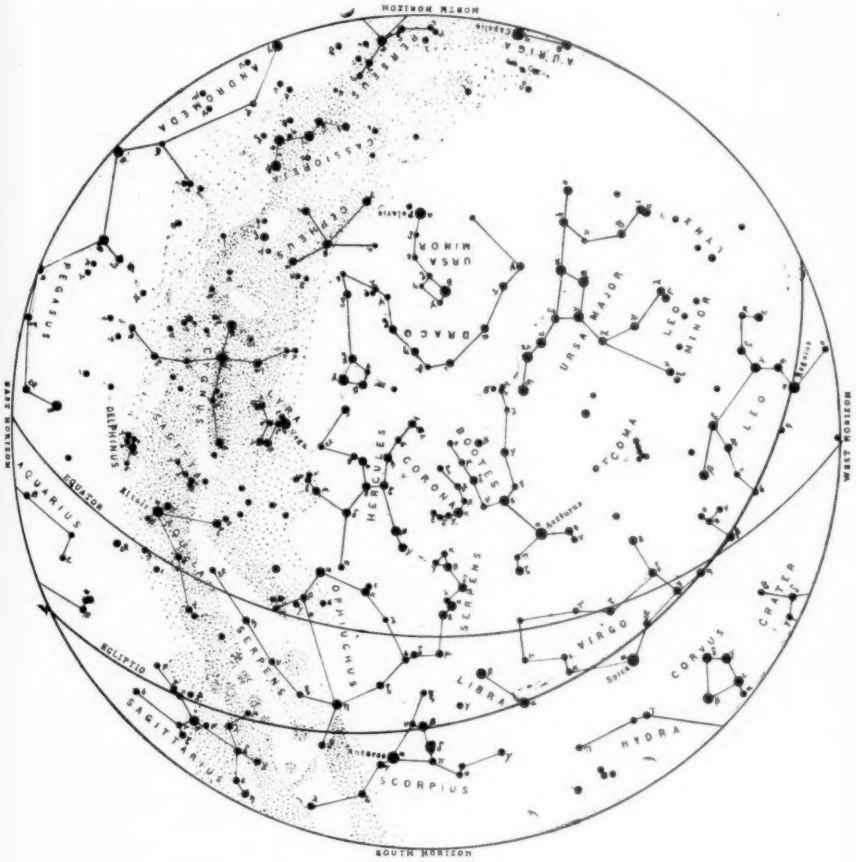
Mars will be an evening star during July and August but will not be in a position favorable to observation. It will move from Cancer into Leo.

Jupiter will be in a very favorable position for observation during both months. It will be near the Moon on July 12 and August 9. The belts of Jupiter are at the present time especially fine and regular. On May 7, seven of them were counted in the 16-inch equatorial and all of them were practically straight and very narrow. The great south equatorial belt was apparently divided into two.

Saturn will be a morning star in the constellation of Pisces and will reach quadrature, 90° west from the Sun on July 29. It will be quite close to the Moon on July 1, July 28 and August 25 and will be stationary in right ascension on August 20, after which date its motion will be retrograde.

Uranus will be at opposition, 180° from the Sun on July 16. It may be found with a telescope about midnight in the constellation Sagittarius. For northern observers the altitude of the planet is too low for satisfactory observations.

Neptune comes into conjunction with the Sun on July 12 and will not be in a position favorable to observation.



THE CONSTELLATIONS AT 9:00 P. M., JULY 1, 1910.

Transit of Jupiter's Satellite I.—Some of our readers are watching the phenomena of Jupiter's satellites and obtaining much pleasure in the study. The following note comes from San Antonio Texas.

"On the 17th of March I observed a transit of Jupiter's satellite I with my 4-inch refractor made by the Mogeys.

The shadow was plainly visible with a power of 168 and afterwards I could see it with a power of 90 as I knew where to look for it. This was before opposition, the shadow being in transit before the satellite.

G. A. DUERLER, JR.

Occultations visible at Washington.

Date 1910	Star's Name	Magnitude.	IMMERSION. Washington M.T. h m	Angle f'm N. °	EMERSION. Washington M.T. h m	Angle f'm N °	Duration. h m
July 3	247 B Tauri	5.8	14 23	120	14 55	201	0 32
16	11 H. Librae	5.4	11 12	83	12 22	310	1 10
23	161 B Capricorni	6.4	15 53	34	16 59	262	1 6
24	69 Aquarii	5.6	10 35	81	11 44	229	1 9
24	τ Aquarii	4.4	12 4	32	13 11	270	1 7
25	376 B Aquarii	6.3	17 46	18	18 44	269	0 58
27	μ Piscium	5.0	17 42	21	18 47	265	1 5
31	103 Tauri	5.5	13 37	7	13 56	320	0 19
Aug. 10	M Virginis	5.4	8 35	89	9 36	322	1 1
15	4 G. Sagittarii	6.2	10 57	111	12 8	245	1 11
18	56 B. Capricorni	6.3	12 14	351	12 33	324	0 19
19	35 Capricorni	6.0	6 5	97	7 6	240	1 1
19	143 B Capricorni	6.1	15 42	102	16 28	202	0 46
27	99 Tauri	6.0	15 7	111	15 59	206	0 52
28	139 Tauri	4.7	14 27	65	15 28	265	1 1
29	39 Geminorum	6.2	14 0	85	14 56	261	0 56
29	40 Geminorum	6.3	14 22	129	15 2	218	0 40

Phenomena of Jupiter's Satellites.

Central Standard Time.

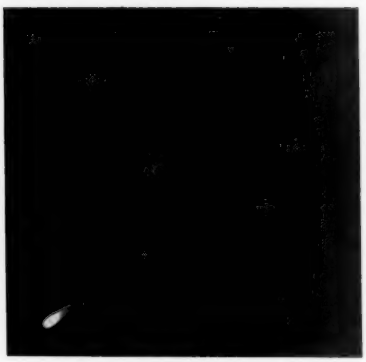
1910	h	m				1910	h	m			
July 3	7	47	I	Tr.	In.	July	8	25	I	Tr.	Eg.
	9	3	I	Sh.	In.	26	8	7	I	Tr.	In.
	10	2	I	Tr.	Eg.	27	7	34	III	Sh.	Eg.
4	8	23	I	Ec.	Re.		8	37	I	Ec.	Re.
6	10	1	II	Oc.	Dis.	31	7	23	II	Oc.	Dis.
8	9	23	II	Sh.	Eg.	Aug. 3	7	16	I	Oc.	Dis.
9	7	27	III	Ec.	Dis.		7	22	III	Tr.	Eg.
	9	29	III	Ec.	Re.	4	6	50	I	Tr.	Eg.
10	9	43	I	Tr.	In.		7	54	I	Sh.	Eg.
12	7	41	I	Sh.	Eg.	9	7	4	II	Tr.	Eg.
15	9	19	II	Sh.	In.	11	6	34	I	Tr.	In.
16	8	53	III	Oc.	Re.		7	35	I	Sh.	In.
17	7	5	II	Ec.	Re.	12	6	56	I	Ec.	Re.
18	8	48	I	Oc.	Dis.	16	7	6	II	Tr.	In.
19	7	22	I	Sh.	In.	18	6	32	II	Ec.	Re.

Note.—In., denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., Transit of the Satellite; Sh., transit of the shadow.

The Total Eclipse May 8, 1910.—A telegram has been received at this Observatory from Professor W. H. Campbell, Director of the Lick Observatory, stating that "Frank McClean cables from Hobart, Tasmania, steady rain, eclipse invisible."

Astronomical Bulletin, No. 404.
Harvard College Observatory.
May 11, 1910.

PLATE XVI.



May 5, 1910, 3:15-3:45 a. m. C.S.T.

May 13, 1910, 3:10-3:37 a. m. C.S.T.

PHOTOGRAPHS OF HALLEY'S COMET
By D. W. Morehouse.

COMET NOTES.

Halley's Comet puzzled many by leaving its tail visible in the east on the morning of May 19, after the head had passed to the west of the Sun. This is not at all difficult to understand if we remember that great comets have at least three types of tail, one nearly straight, probably composed of the lightest gases like hydrogen and helium, a second considerably curved toward the rear of the comets motion, composed mostly of the compounds of carbon and hydrogen, and a third much shorter and curved far back, composed of the heavier vapors like those of sodium and iron. The first of these tails was the only one straight enough for the Earth to have passed through it on the night of May 18. Whether Halley's comet has all three types of tail does not appear yet from the observations, for, except for a few days while the moonlight has been so bright as to obliterate the fainter parts of the tail, the position of the Earth has been such that the three tails were projected the one very nearly upon the other and the curve appeared very nearly straight. Wednesday and Thursday mornings May 18 and 19, the tail extended around to the constellation Aquila, the end being lost in the light of the Milky Way. Last evening May 22, the head of the comet was conspicuous in the west from 8:15 to 9:30, looking like a hazy star of half the diameter of the Moon. The tail extended approximately toward Jupiter and could be traced for about 10° length in the full moonlight. It broadened rapidly being at least 2° wide at 10° from the head. During the first two weeks of June the comet should be a fine object, seen toward the southwest as soon as the twilight darkens sufficiently.

The following notes are extracted from letters received from Professor E. E. Barnard of the Yerkes Observatory within the last few days:

"Sunday morning (May 15) the sky was hazy and there was a band of haze and smoke in the east that hid the head of the comet until 3:40 when the nucleus became visible in the 5-inch guiding telescope of the Bruce photographic telescope. At 2:40 and for 10 or 15 minutes later I could see the tail stretching above the haze bank and could trace it to and slightly beyond the star θ Pegasi. This would make it about 50° long. At about three-fourths its length from the head it was 3° or 4° broad. It seemed straight. The nucleus in the 5-inch, when best seen, was less bright than Venus appeared to the naked eye at the same altitude. The nucleus was therefore many times less bright than Venus."

"On the morning of May 18, the tail was 107° long and 5°—6° wide. On morning of May 19, the tail was 120° long and near the horizon it was 10° wide and about as bright as the brightest part of the Milky Way."

According to the Harvard Circular No. 406, Mr. Joel H. Metcalf observed the tail of the comet on the morning of May 18, making its length about 120° and its width 11°. Its end was near θ Aquilæ and its center near γ Pegasi. "It is now 4° more nearly in the ecliptic than yesterday."

In the Harvard Astronomical Bulletin, May 19, Professor W. W. Campbell, Director of the Lick Observatory, states that Halley's comet was visible in the eastern sky this morning. The tail was at least one hundred and forty degrees long, and lags far behind the radius vector. The opinion is expressed that the Earth will probably not pass through the tail.

A telegram from Professor Pickering May 21, says: "Innes Johannesburg (South Africa) telegraphs Halley's evening tail 19° also branched tail visible this morning."

Photographs of Halley's Comet. I am sending you under separate cover two positives of Halley's comet, one for May 5; the other for May 13. You will note in the latter some interesting detail in the coma. First the dark streak down the center of the tail which seems to reverse into a light one at some distance from the coma. The delicate sheath is seen to envelope the head. You will no doubt note the bulge on one side of the tail a little distance from the coma. All this detail was plainly visible through the 8¼-inch telescope. I do not know that this detail is strong enough for reproduction in your magazine, but I am sending them and hope that they may be of some service to you. The negative was taken on a Lumiere Sigma plate, from 3:10 to 3:27 on the morning of the 13th. The one on the 5th of May shows four distinct bright rays diverging from the bright coma. The shape of the head is also quite interesting. This photograph was taken on a Seed-27 from 3:18 to 3:58.

D. W. MOREHOUSE.

Des Moines, Iowa, May 16 1910.

The Passage of Halley's Comet, May 18.—On the night of May 18, watch was kept at all the observatories for any phenomena which might appear at the time of the Earth's passage through the plane of the comet's orbit. The only effect noticed at Northfield was an aurora in the northern sky, which was quite active at about the predicted time of the Earth's entrance into the comets tail, but which may have had no connection whatever with it. The bright moonlight obliterated all trace of objects as faint as a comets tail. No reports have yet been received from points on the Pacific Islands where the transit of the comet across the Sun may have been observed.

Telegrams from Professor Kobold of Kiel, Germany, and Professor Leuschner of Berkeley, Cal., give the same predicted time for the middle of the transit, May 18, 16^h 7.0 , Greenwich mean time, based on the most accurate recent observations of the comet.

The Passage of Halley's Comet, May 18.—At the Washburn Observatory, independent watches were kept by Mr. Flint and myself on the night of May 18, from early evening until the appearance of strong morning twilight without finding any indication of phenomena that could be attributed to the tail of Halley's comet. A well marked auroral display was seen about 9 P. M., which subsequently disappeared and reappeared between 2 and 3 A.M. During the period last named, a vague band of light was faintly seen in the eastern sky presenting some resemblance to the zodiacal light, but too remote from the ecliptic to be identified with it. The night was clear, but the sky was slightly milky in appearance to such an extent that the galaxy, although distinctly visible, was inconspicuous even after the Moon had set.

GEORGE C. COMSTOCK.

Washburn Observatory, May 19, 1910.

The Passage of Halley's Comet, May 18.—Professor Comstock has prepared a note of the results of our watch of the sky last night, but I thought it would be well to send you a separate, more definite report of my watch for evidences of the comet to be compared with reports from other observers.

I was busy with public visitors at the observatory until 10:45 but noticed a bright but ordinary aurora over the northern horizon in the course of the

evening. (A local paper reports that the display continued from 9:20 till 9:35.) It had disappeared by 10:45.

At 12 hours I began keeping a watch of the sky. From about 14:00 to 14:15 I saw a very low, faint auroral arc over the north point of the horizon. I was walking upon the driveways to the westward of the observatory and city, and upon turning into a road running south, I suddenly noticed a faint but decided streak of white light athwart the eastern sky. This was at about 14:15. The auroral arc in the north had disappeared and the Moon was low on the western horizon. The streak of light had an obscure beginning east of γ Pegasi, passed between γ and α Pegasi, including both stars within its borders, the latter farther in than the former, passed between θ and ϵ Pegasi, with these two stars situated on the northern and southern edges respectively, and terminated at θ Aquilae, falling short of joining the Milky Way, which while plainly seen, was not of normal brightness. The streak narrowed gradually throughout its length, from east to west, or seemed to, until it terminated in a faint, thin tip at θ Aquilæ. Referring to the star map, I found I had traced it nearly 70 degrees in length, with a width of 5 or 6 degrees in its middle portion. Its axis ran nearly parallel to the ecliptic and 16 or 17 degrees north of it. This light was remarkably steady. I did not notice any wavering in its position or variability among its parts in relative position or brightness.

At 14:45 the dawn was plainly visible revealing low bands of dense clouds over the northeastern horizon. At about 15:00, as I was watching the streak of light, it diminished rapidly in brightness. At 15:05 there was stil a faint trace of it, but I should hardly have noticed it then at first sight. At 15:32 ζ Pegasi was just visible in the light of dawn.

At about 12:45 I saw one meteor, rather slow moving and with a short train passing northeasterly across the southern portion of the constellation Hercules.

ALBERT L. FLINT.

Washburn Observatory, May 19, 1910.

Elliptic Elements of Comet *a* 1910.—In *A. N.* 4398 Mr M. S. de Mello e Simas of Lisbon gives the following elements of comet *a* 1910, derived from three normal places dated Jan. 24, Jan. 30 and Feb. 8:

$$\begin{aligned} T &= 1910 \text{ Jan. } 17.11310 \text{ Berlin m. t.} \\ \omega &= 320^\circ\ 28'\ 24''.1 \\ \Omega &= \ \ 88\ \ 39\ \ 47\ \ .6 \quad 1910.0 \\ i &= 138\ \ 44\ \ 22\ \ .0 \\ \log q &= 9.1086880 \\ e &= 0.9962765 \end{aligned}$$

Definitive Orbit of Comet 1883 II (Ross).—In *A. N.* 4400 Mr. Eduard Moravi gives the results of a definitive determination of the orbit of the comet discovered by David Ross at Elsternwick near Melbourne on Jan. 4, 1884. The comet was observed only about a month so the determination of exact elements was difficult but an ellipse appears to satisfy the observations better than a parabola. The period comes out 64.63 years

$$\begin{aligned} T &= 1883 \text{ Dec. } 25.14860 \text{ Berlin m. t.} \\ \omega &= 137^\circ\ 36'\ 26''.79 \\ \Omega &= 264\ \ 17\ \ 47\ \ .78 \\ i &= 114\ \ 41\ \ 57\ \ .09 \\ \log q &= 9.4893613 \\ e &= 0.9808396 \end{aligned}$$

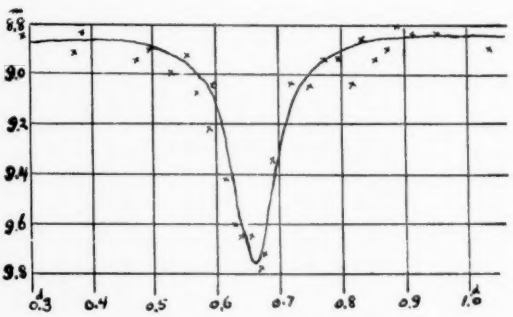
Ephemeris of Halley's Comet.

Greenwich Midnight 1910		R. A. h	m	s	Decl. °	′	″	log r	log Δ
Aug.	4	11	13	17	— 5	39	32	0.30316	0.42571
	8	11	16	2	— 6	0	26	0.31502	0.44240
	12	11	18	47	— 6	21	31	0.32636	0.45777
	16	11	21	30	— 6	42	53	0.33732	0.47200
	20	11	24	9	— 7	4	22	0.34800	0.48520
	24	11	26	47	— 7	26	13	0.35832	0.49740
	28	11	29	24	— 7	48	10	0.36818	0.50856
Sept.	1	11	31	57	— 8	10	19	0.37784	0.51889
	5	11	34	26	— 8	32	40	0.38736	0.52852
	9	11	36	54	— 8	55	9	0.39644	0.53719
	13	11	39	18	— 9	17	51	0.40532	0.54517
	17	11	41	38	— 9	40	37	0.41392	0.55242
	21	11	43	56	—10	3	32	0.42228	0.55895
	25	11	46	11	—10	26	28	0.43042	0.56483
Oct.	23	11	59	2	—13	7	1	0.48226	0.58941
	27	12	0	24	—13	29	34	0.48902	0.59078
	31	12	1	38	—13	51	48	0.49560	0.59161
Nov.	4	12	2	44	—14	13	54	0.50200	0.59202
	8	12	3	38	—14	35	36	0.50834	0.59197
	12	12	4	23	—14	57	23	0.51444	0.59142
	16	12	4	54	—15	17	41	0.52056	0.59059
	20	12	5	15	—15	38	12	0.52642	0.58922
	24	12	5	22	—15	57	56	0.53228	0.58758
	28	12	5	14	—16	16	55	0.53802	0.58559
Dec.	2	12	4	54	—16	35	23	0.54352	0.58316
	6	12	4	16	—16	52	44	0.54904	0.58055

F. E. SEAGRAVE.

VARIABLE STARS.

The Variable 62.1907 Scuti.—In *A. N.* 4403 Mr. Naozo Ichinohe gives a light-curve of this very short period star of the Algol type. The vari-



LIGHT CURVE OF 62.1907 SCUTI.

able ranges from $8^m.9$ at normal to $9^m.8$ at minimum. The period is $15^h\ 56^m\ 44^s$ and the light change occupies about eight hours,

Min. = 2418424.26 Gr. M. T. + $0^d.66440$ E

New Variable 26.1910 Scuti.—This is announced by Mr. Naozo Ichinohe in in *A. N.* 4397. It is the star B. D. —10° 4821 ($9^m.5$) the position of which for 1855.0 is

$$\alpha\ 18^h\ 41^m\ 36^s \qquad \delta - 10°\ 32'.8.$$

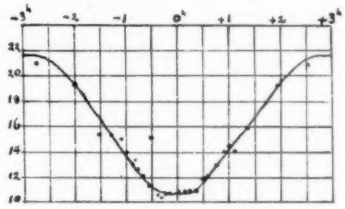
The variable is of the cluster type, coming to a maximum every half day. Mr. Ichinohe derives the elements.

$$\text{Max.} = 2417729.080\ \text{Gr. m. t.} + 0^d.49564\ \text{E.}$$

The range of variation is about $0^m.63$ or from magnitude 9.7 to magnitude 9.1. The increase in brightness occupies about two hours and the decrease three and a half hours.

New Algol Type Variable 28.1910 Cygni.—In *A.N.* 4398 Mr A. Stanley Williams gives elements and light curve of a new variable, 28.1910 Cygni, of the Algol type. Its position is

α 1855	δ 1855	α 1900	δ 1909
$21^h\ 07^m\ 06^d$	$+30°\ 08'.6$	$21^h\ 09^m\ 00^s$	$+30°\ 19'.6$



LIGHT CURVE OF 28.1910 CYGNI.

Its normal brightness is at magnitude 10.8, but at minimum it goes down to $11^m.4$. The period is $23^h\ 15^m\ 37^s.7$ the adopted elements being

$$\text{Min.} = 2415704.451 + 0^d.969186\ \text{E.}$$

Mr. Williams gives the following list of comparison stars with his light-scale;

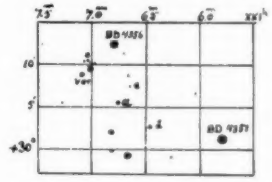


CHART OF 28.1910 CYGNI.

Star	α 1855.0 h m s	δ 1855.0 ° ′	Brightness steps	Mag. m
a	21 06 47	+ 30 05.3	32.3	10.30
d	21 06 28	+ 30 02.7	27.5	10 54
e	21 06 39	+ 30 07.4	12.5	11.29
c	21 07 03	+ 30 10.3	11.8	11.32
b	21 07 01	+ 30 10.2	10.0	11.41

New Variable 32.1910 Aquilæ.—This was discovered by Miss Caroline Furness of Vassar College Observatory. It is the star B D — 7° 4896 (9^m.7) and its position is

α 1855	δ 1855	α 1900	δ 1900
h m s	° ′	h m s	° ′
19 07 19.0	— 7 15.5	19 09 44.5	— 7 11.0

The variation is between magnitudes 10 and 11. The star is 15^s preceding and 2′ north of the variable W Aquilæ.

New Variables 33 and 34.1910.—In *A. N.* 4400 Mr. S. Enebo of Dombaas, Norway, calls attention to two new variables. Their positions are

	α 1855.0	δ 1855.0	α 1900.0	δ 1900.0
	h m s	° ′ ″	h m s	° ′ ″
33.1910 Cygni	20 25 56.97	+32 02 02.6	20 27 44.96	+32 11 02.1
34.1910 Lacertæ	22 38 42.4	+48 54.2	22 40 36.4	+49 08.2

The first is B. D. +32°3852, the magnitude of which is given in the B. D. as 9.0. Its range appears to be from about 8^m.6 to 9^m.7, the period being unknown.

The second is probably of the Algol type, with a period of possibly 5.18 days.

New Variable 35.1910 Cygni.—This is announced in *A. N.* 4400 by Professor W. Ceraski of Moscow. Its position is

α 1855.0	δ 1855.0	α 1900.0	δ 1900.0
h m s	° ′	h m s	° ′
19 14 59	+29 14.5	19 16 45	+29 19.4

On 28 photographs taken between 1898 and 1910 the brightness varies between 9^m.8 and 10^m.7. The period is short or quite irregular.

New Variables 36 and 37.1910 Herculis.—In *A. N.* 4403 Professor Ceraski announces two new variable stars discovered by Mme. L. Ceraski. Their positions are

	α 1855.0	δ 1855.0	α 1900.0	δ 1900.0
	h m s	° ′	h m s	° ′
36.1910 Herculis	18 09 15	+31 47	18 10 56	+31 48
37.1910 Herculis	17 08 01.4	+30 53.9	17 09 44.6	+30 50.6

The first varies between magnitudes 9 and 11, the type and period being unknown.

The second is probably of the Algol type and varies between magnitudes 9.5 and 11.0. The period is unknown.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours, etc. For stars marked with an * alternate minima are given; ** every third minimum; † every tenth minimum.]

SY Androm.

	d	h
July	24	14
Aug.	28	12

*U Cephei

July	3	12
	8	11
	13	11
	18	11
	23	10
	28	10
Aug.	2	10
	7	9
	12	9
	17	9
	22	8
	27	8

*Z Persei

July	2	6
	8	9
	14	12
	20	14
	26	17
Aug.	1	20
	7	22
	14	1
	20	4
	26	7

RY Persei

July	2	2
	8	23
	15	20
	22	16
	29	13
Aug.	5	10
	12	7
	19	3
	26	0

**RZ Cassiop.

July	1	7
	4	21
	8	11
	12	1
	15	15
	19	5
	22	19
	26	9
	29	23
Aug.	2	13
	6	3
	9	17
	13	7
	16	21
	20	11
	24	2
	27	16
	31	6

ST Persei

	d	h
July	2	16
	7	23
	13	6
	18	13
	23	20
	29	4
Aug.	3	11
	8	18
	14	1
	19	8
	24	15
	29	22

RX Cephei

July	15	10
Aug.	16	18

*Algol

July	2	3
	7	20
	13	14
	19	7
	25	1
	30	19
Aug.	5	12
	11	6
	17	0
	22	17
	28	11

**RT Persei

July	2	11
	5	1
	7	14
	10	3
	12	16
	15	5
	17	18
	20	8
	22	21
	25	20
	27	23
	30	12
Aug.	2	1
	4	14
	7	4
	9	17
	12	6
	14	19
	17	8
	19	21
	22	11
	25	0
	27	13
	30	2

λ Tauri

July	1	8
	5	7
	9	6

λ Tauri

	d	h
July	13	5
	17	3
	21	2
	25	1
	29	0
Aug.	1	23
	5	22
	9	21
	13	19
	17	18
	21	17
	25	16
	29	15

*RW Tauri

July	1	5
	6	18
	12	7
	17	20
	23	9
	28	21
Aug.	3	10
	8	23
	14	12
	20	1
	25	14
	31	3

*RV Persei

July	1	12
	5	11
	9	10
	13	9
	17	7
	21	6
	25	5
	29	4
Aug.	2	2
	6	1
	10	0
	13	22
	17	21
	21	20
	25	19
	29	17

RW Persei

July	3	15
	16	19
	30	0
Aug.	12	5
	25	10

RS Cephei

July	1	11
	13	21
	26	7
Aug.	7	17
	20	3

*RY Aurigæ

	d	h
July	5	10
	10	21
	16	8
	21	19
	27	6
Aug.	1	16
	7	3
	12	14
	18	1
	23	12
	28	23

* RZ Aurigæ

July	1	18
	7	19
	13	19
	19	20
	25	21
	31	22
Aug.	6	22
	12	23
	19	0
	25	1
	31	1

*RW Gemin.

July	2	17
	8	11
	14	4
	19	22
	25	15
	31	9
Aug.	6	2
	11	20
	17	13
	23	7
	29	0

*U Columbæ

July	1	5
	6	19
	12	10
	18	0
	23	15
	29	5
Aug.	3	19
	9	10
	15	0
	20	15
	26	5
	31	19

*RW Monoc.

July	1	19
	5	14
	9	10
	13	5
	17	1
	20	20
	24	16
	28	11

*RW Monoc.

	d	h
Aug.	1	7
	5	2
	8	22
	12	17
	16	13
	20	8
	24	4
	27	23
	31	19

RX Gemin.

July	8	7
	20	12
Aug.	1	17
	13	22
	26	3

**RU Monoc.

July	3	15
	6	7
	9	0
	11	16
	14	9
	17	1
	19	18
	22	10
	25	3
	27	19
	30	12
Aug.	2	4
	4	21
	7	13
	10	6
	12	22
	15	15
	18	7
	22	0
	23	16
	26	9
	29	2
	31	18

RY Geminorum

July	8	16
	17	23
	27	6
Aug.	5	14
	14	21
	24	4

**R Canis Maj.

July	2	16
	6	2
	9	12
	12	21
	16	7
	19	17
	23	3
	26	12
	29	22

Minima of Variable Stars of the Algol Type.—Continued.

**R Canis Maj.

d	h
Aug. 2	8
5	18
9	4
12	13
15	23
19	9
22	19
26	5
29	14

*Y Camelop.

d	h
July 5	6
11	20
18	11
25	2
31	16
Aug. 7	7
13	22
20	12
27	3

RR Puppis

d	h
July 1	5
7	16
14	2
20	12
26	23
Aug. 2	9
8	19
15	6
21	16
28	2

**V Puppis

d	h
July 2	5
6	14
10	22
15	7
19	16
24	1
28	9
Aug. 1	18
6	3
10	12
14	20
19	5
23	14
27	22

†X Carinæ

d	h
July 1	17
7	3
12	13
17	23
23	9
28	19
Aug. 3	5
8	15
14	1
19	11
24	21
30	7

S Cancri

d	h
July 7	1
16	14
26	1
Aug. 4	13
14	1
23	12

S Velorum

d	h
July 1	6
7	4
13	3
19	1
25	0
30	22
Aug. 5	20
11	19
17	17
23	16
29	14

**Y Leonis

d	h
July 7	11
12	12
17	14
22	15
27	16
Aug. 1	18
6	19
11	21
16	22
22	0
27	1

**RR Velorum

d	h
July 5	5
10	18
16	8
21	21
27	11
Aug. 2	0
7	14
13	3
18	17
24	6
29	20

*SS Carinae

d	h
July 4	7
10	22
17	42
24	3
30	17
Aug. 6	8
12	22
19	12
26	3

RW Urs. Maj.

d	h
July 2	13
9	21
17	5
24	13
31	21
Aug. 8	4
15	12
22	20
30	4

**Z Draconis

d	h
July 3	22
8	0
12	2
16	4
20	5
24	7
28	9
Aug. 1	11
5	12
9	14
13	16
17	18
21	19
25	21
29	23

*SS Centauri

d	h
July 1	7
6	6
11	5
16	4
21	3
26	2
31	1
Aug. 5	0
9	23
14	22
19	21
24	20
29	19

*δ Libræ

d	h
July 3	7
7	23
12	14
17	6
21	22
26	13
31	5
Aug. 4	21
9	13
14	4
18	20
23	12
28	3

*U Coronæ

d	h
July 7	18
14	16
21	13
28	11
Aug. 4	9
11	7
18	4
25	12

*SW Ophiuchi

d	h
July 3	1
7	23
12	20
17	17
22	15
27	12
Aug. 1	9
6	7
11	4
16	2
20	23
25	20
30	18

*SX Ophiuchi

d	h
July 2	8
6	11
10	14
14	17
18	20
22	23
27	2
31	5
Aug. 4	8
8	11
12	14
16	17
30	20
24	24
29	2

R Aræ

d	h
July 4	11
8	21
13	7
17	17
22	3
26	14
31	0
Aug. 4	10
8	20
13	6
17	17
22	3
26	13
30	23

**U Ophiuchi

d	h
July 3	4
5	16
8	5
10	17
13	5
15	18
18	6
20	19
23	7
25	19
28	8
30	20

**U Ophiuchi

d	h
Aug. 2	8
4	21
7	9
9	22
12	10
14	22
17	11
19	23
22	12
25	0
27	12
30	1

**SZ Herculis

d	h
July 1	9
3	20
6	7
8	17
11	4
13	15
16	2
18	13
21	0
23	11
25	22
28	9
30	20
Aug. 2	6
4	17
7	4
9	15
12	2
14	13
17	0
19	11
21	22
24	9
26	20
29	6
31	17

Z Herculis

d	h
July 2	21
6	21
10	21
14	21
18	21
22	20
26	20
30	20
Aug. 3	20
7	20
11	20
15	19
19	19
23	19
27	19
31	19

*RS Sagittarii

d	h
July 3	19
8	15

Minima of Variable Stars of the Algol Type.—Continued.

*RS Sagittarii

d	h
July 13	11
18	7
23	3
27	23
Aug. 1	19
6	15
11	11
16	7
21	3
26	23
30	18

*V Serpentis

July 7	19
14	17
21	15
28	14
Aug. 4	12
11	9
18	7
25	5

†RZ Draconis

July 4	15
10	4
15	16
21	4
26	16
Aug. 1	4
6	17
12	5
17	17
23	5
28	17

**RX Herculis

July 3	11
6	3
8	19
11	11
14	3
16	19
19	11
22	3
24	19
27	11
30	3
Aug. 1	19
4	11
7	3
9	19
12	11
15	3
17	19
20	11
23	3
25	20
28	12
31	4

*SX Sagittarii

July 2	23
7	3
11	7
15	10
19	14
23	18
27	22
Aug. 1	1
5	5
9	9
13	12
17	16
21	20
25	23
30	3

*RR Draconis

July 2	13
8	5
13	21
19	13
25	5
30	21
Aug. 5	3
11	5
16	21
22	12
29	4

**U Scuti

July 2	14
5	10
8	7
11	4
14	1
16	21
19	18
22	15
25	12
28	8
31	5
Aug. 3	2
5	23
8	19
11	16
14	13
17	10
20	6
23	3
26	0
28	21
31	18

*RX Draconis

July 1	18
5	12
9	7
13	2
16	21
20	16
24	11
28	6
Aug. 1	0
4	18

*RX Draconis

Aug. 8	13
12	8
16	3
19	23
23	18
27	13
31	8

*RV Lyræ

July 4	17
11	22
19	3
26	7
Aug. 2	12
9	17
16	22
24	2
31	7

*U Sagittae

July 4	22
11	16
18	10
25	4
31	23
Aug. 7	17
14	11
21	6
28	0

Z Vulpeculæ

July 2	22
7	23
13	1
18	2
23	3
28	4
Aug. 2	5
7	7
12	8
17	9
22	10
27	11

SY Cygni

July 2	4
8	4
14	4
20	4
26	4
Aug. 1	4
7	5
13	5
19	5
25	5
31	5

*WW Cygni

July 6	3
12	18
19	10
29	1
Aug. 1	16
8	7

*WW Cygni

d	h
Aug. 14	23
21	14
28	5

ZW Cygni

July 3	23
8	12
13	2
17	16
22	6
26	19
31	9
Aug. 4	23
9	13
14	2
18	16
23	6
27	20

VW Cygni

July 7	22
16	8
24	19
Aug. 2	5
10	15
19	2
27	12

*UW Cygni

July 2	1
8	22
15	20
22	18
29	15
Aug. 5	13
12	11
19	8
26	6

W Delphini

July 3	10
8	5
13	0
17	20
22	15
27	10
Aug. 1	6
6	1
10	21
15	16
20	11
25	7
30	2

RR Delphini

July 1	22
6	12
11	2
15	17
20	7
24	21
29	12

RR Delphini

d	h
Aug. 3	2
7	17
12	8
16	21
21	12
26	2
30	16

RR Vulpeculae

July 4	24
10	1
15	2
20	4
25	5
30	6
Aug. 4	7
9	8
14	10
19	11
24	12
29	13

**VV Cygni

July 3	22
8	9
12	19
17	5
21	16
26	2
30	12
Aug. 3	23
8	9
12	19
17	6
21	16
26	2
30	13

UZ Cygni

July 21	2
Aug. 21	9

*RT Lacertae

July 3	9
8	10
13	12
18	14
23	16
28	17
Aug. 2	19
7	21
12	23
18	0
23	2
28	4

*TT Androm.

July 4	17
10	6
15	18
20	7
26	20
31	8

Minima of Variable Stars of the Algol Type.—Continued.

*TT Androm.		*TT Androm.		21.1910 Andr.		21.1910 Andr.		21.1910 Andr.	
d	h	d	h	d	h	d	h	d	h
Aug. 6	21	Aug. 29	0	July 10	18	July 27	5	Aug. 12	16
12	10	21.1909 Andr.		14	20	31	7	16	18
17	22	July 2	12	18	23	Aug. 4	10	20	21
23	11	6	15	23	2	8	13	25	0
								29	3

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SX Cassiop.		SU Cassiop.		SX Aurigae		Y Aurigae		ζ Geminorum	
d	h	d	h	d	h	d	h	d	h
July 9	12	Aug. 7	8	July 26	13	July 17	11	July 22	8
Aug 15	2	9	7	28	2	21	8	Aug. 1	12
SY Cassiop.		11	5	29	15	25	4	11	16
July 2	23	13	4	31	3	29	1	21	19
7	1	15	3	Aug. 1	6	RZ Geminorum		31	23
11	3	17	2	3	5	(−1 7)		RU Camelop.	
15	5	19	1	4	18	July 6	0	(−9 12)	
19	6	20	23	6	6	11	13	July 14	3
23	8	22	22	7	19	17	1	Aug. 5	9
27	10	24	21	9	8	22	13	27	16
31	11	26	20	10	21	28	2	V Carinæ	
Aug. 4	13	28	18	12	9	Aug. 2	14	(− 2 4)	
8	15	30	17	13	22	8	2	July 3	9
12	16	SV Persei		15	11	13	15	10	2
16	18	July 2	9	16	24	19	3	16	18
20	20	13	12	18	12	24	15	23	11
24	22	24	15	20	1	30	4	30	4
28	23	Aug. 4	18	21	14	RS Orionis		Aug. 5	20
RW Cassiop.		15	21	23	3	(−2 0)		12	13
(−5 19)		27	0	24	15	July 2	11	19	6
July 15	2	RX Aurigæ		26	4	10	00	25	23
29	22	(−4 0)		27	17	17	13	T Velorum	
Aug. 13	17	July 8	23	29	6	25	3	(− 1 10)	
28	12	20	14	30	19	Aug. 1	16	July 1	18
SU Cassiop.		Aug. 1	6	SY Aurigae		9	6	6	10
(−0 22)		12	21	July 4	6	16	19	11	1
July 1	7	24	12	14	9	24	9	15	16
3	6	SX Aurigae		24	12	31	22	20	8
5	5	July 2	1	Aug. 3	16	T Monoc.		24	23
7	3	3	14	13	19	(−9 23)		29	14
9	2	5	2	23	22	July 18	19	Aug. 3	6
11	1	6	15	Y Aurigæ		14	20	7	21
12	24	8	4	(−0 18)		W Geminorum		12	12
14	23	9	17	July 2	4	(−2 2)		17	4
16	21	11	5	6	0	July 2	1	21	19
18	20	12	18	9	21	9	23	26	10
20	19	14	7	13	17	17	21	31	2
22	18	15	20	17	14	25	19	W Carinæ	
24	16	17	9	21	11	Aug. 2	17	(−1 0)	
26	15	18	21	25	7	10	15	July 2	22
28	14	20	10	29	4	18	13	7	7
30	13	21	23	Aug. 2	1	26	11	11	16
Aug. 1	12	23	12	5	21	ξ Geminorum		15	1
3	10	25	0	9	18	(−5 0)		19	10
5	9			13	14	July 2	1	23	19
						12	5		

Maxima of Variable Stars of Short Period not of the Algol Type. Con.

W Carinæ

	d	h
July	28	3
Aug.	1	12
	5	21
	10	6
	14	15
	18	24
	23	9
	27	18

S Muscæ

(−3 11)

July	10	0
	19	16
	29	8
Aug.	7	24
	17	15
	27	7

T Crucis

(−2 2)

July	5	23
	12	16
	19	10
	26	3
Aug.	1	21
	8	14
	15	8
	22	2
	28	19

R Crucis

(−1 10)

July	1	8
	7	3
	12	23
	18	19
	24	15
	30	11
Aug.	5	6
	11	2
	16	22
	22	18
	28	14

S Crucis

(−1 12)

July	5	13
	10	6
	14	23
	19	15
	24	8
	29	0
Aug.	2	17
	7	9
	12	2
	16	18
	21	11
	26	4
	30	20

RZ Centauri

July	1	12
	2	10
	3	9
	4	7
	5	6
	6	4
	7	3

RZ Centauri

	d	h
July	8	1
	9	0
	9	22
	10	21
	11	19
	12	18
	13	16
	14	15
	15	13
	16	12
	17	10
	18	9
	19	18
	20	6
	21	5
	22	3
	23	2
	24	0
	24	23
	25	21
	26	20
	27	18
	28	17
	29	15
	30	14
	31	12
Aug.	1	11
	2	9
	3	8
	4	6
	5	5
	6	3
	7	2
	8	0
	8	23
	9	21
	10	20
	11	18
	12	17
	13	15
	14	14
	15	12
	16	11
	17	9
	18	8
	19	6
	20	5
	21	3
	22	2
	23	0
	23	23
	24	21
	25	20
	26	18
	27	17
	28	15
	29	14
	30	13
	31	11

W Virginis

(−8 5)

July	3	18
	21	0

W Virginis

	d	h
Aug.	2	7
	24	14

V Centauri

(−1 11)

July	1	19
	7	7
	12	19
	18	7
	23	19
	29	7
Aug.	3	18
	9	6
	14	18
	20	6
	25	18
	31	6

R Triang. Austr.

(−1 0)

July	2	1
	5	10
	8	20
	12	5
	15	14
	18	24
	22	9
	24	18
	28	4
Aug.	1	13
	4	22
	8	8
	11	17
	15	3
	18	12
	21	21
	25	7
	28	16

S Triang. Austr.

(−2 2)

July	2	5
	8	13
	14	20
	21	4
	27	12
Aug.	2	20
	9	4
	15	11
	21	19
	28	3

S Normæ

(−4 10)

July	9	4
	18	22
	28	17
Aug.	7	11
	17	5
	26	23

RV Scorpii

(−1 10)

July	4	8
	10	10
	16	11
	22	13
	28	14

RV Scorpii

	d	h
Aug.	3	16
	9	17
	15	19
	21	20
	27	22

RV Ophiuchi Minimum

July	4	15
	8	7
	11	24
	15	16
	19	9
	23	1
	26	18
	30	10
Aug.	3	3
	6	19
	10	12
	14	4
	17	21
	21	13
	25	6
	28	22

X Sagittarii

(−2 22)

July	2	9
	9	10
	16	10
	23	10
	30	11
Aug.	6	11
	13	11
	20	11
	27	12

Y Ophiuchi

(−6 5)

July	10	23
	28	2
Aug.	14	5
	31	7

W Sagittarii

(−3 0)

July	5	21
	13	11
	21	1
	28	16
Aug.	5	6
	12	20
	28	01

Y Sagittarii

(−2 2)

July	5	7
	11	2
	16	20
	22	15
	28	9
Aug.	3	4
	8	22
	14	17
	20	12
	26	6

U Sagittarii

	d	h
	(−2	23)
July	7	13
	14	7
	21	1
	27	19
Aug.	3	13
	10	7
	17	0
	23	18
	30	12

β Lyræ

(−3 7)
(−3 2)

July	2	16
	9	8
	15	14
	22	6
	28	12
Aug.	4	4
	10	10
	17	2
	23	8
	30	0

κ Pavonis

(−4 7)

July	3	23
	13	1
	22	4
	31	6
Aug.	9	8
	18	10
	27	12

U Aquilæ

(−2 4)

July	5	20
	12	21
	19	21
	26	22
Aug.	2	22
	9	23
	17	00
	24	00
	31	1

U Vulpeculæ

(−2 3)

July	6	15
	14	14
	22	14
	30	13
Aug.	7	13
	15	12
	23	12
	31	11

SU Cygni

(−1 7)

July	3	0
	6	21
	10	17
	14	13
	18	10
	22	6
	26	2
	29	22

Maxima of Variable Stars of Short Period not of the Algol Type.-Con.

SU Cygni

	d	h
Aug.	2	19
	6	15
	10	11
	14	8
	18	4
	22	0
	25	21
	29	17

η Aquilae

	(−2	6)
July	7	8
	14	12
	21	17
	28	21
Aug.	5	1
	12	7
	19	10
	26	14

S Sagittae

	(−3	10)
July	5	20
	14	5
	22	15
	30	24
Aug.	8	10
	16	18
	25	3

X Vulpeculae

	(−2	1)
July	1	7
	7	14
	13	22
	20	6
	26	13
Aug.	1	21
	8	4
	14	12
	20	20
	27	3

V Vulpeculae Minimum

	d	h
July	14	18
Aug.	21	13

X Cygni

	(−6	19)
July	5	20
	21	5
Aug.	6	14
	23	0
	19	23
	25	10
	30	20

T Vulpeculae

	(−1	10)
July	5	2
	9	12
	13	23
	18	9
	22	20
	27	6
	31	17
Aug.	5	3
	9	14
	14	00
	18	10
	22	21
	27	7
	31	18

TX Cygni

July	1	5
	15	23
	30	16
Aug.	14	10
	29	3

VY Cygni

	(−2	14)
July	1	11
	9	8
	17	5

VV Cygni

	d	h
July	25	12
	1	22
	9	18
	17	15
	25	12

VZ Cygni

	(−1	1)
July	3	14
	8	11
	13	7
	18	4
	23	1
	27	22
Aug.	1	18
	6	15
	11	12
	16	8
	21	5
	26	2
	30	23

Y Lacertae

	(−1	10)
July	4	4
	8	11
	12	19
	17	3
	21	11
	25	19
	30	2
Aug.	3	10
	7	18
	12	2
	16	10
	20	17
	25	1
	29	9

δ Cephei

	d	h
July	2	6
	7	15

δ Cephei

	d	h
July	12	23
	18	8
	23	17
	29	2
Aug.	3	11
	8	19
	14	4
	19	13
	24	22
	30	7

Z Lacertae

	d	h
July	3	6
	14	3
	25	00
Aug.	4	21
	15	18
	26	15

RR Lacertae

	d	h
July	4	4
	10	14
	17	00
	23	11
	29	21
Aug.	5	7
	11	17
	18	3
	24	13
	30	23

V Lacertae

	(−1	16)
July	1	4
	6	3
	11	3
	16	3
	21	2
	26	2
	31	1
Aug.	5	1
	10	1

V Lacertæ

	d	h
Aug.	15	0
	20	0
	24	23
	29	23

X Lacertae

July	1	23
	7	10
	12	21
	18	7
	23	18
	29	4
Aug.	3	15
	9	2
	14	12

SW Cassiop.

July	4	18
	10	4
	15	15
	21	1
	26	12
	31	22
Aug.	6	8
	11	19
	17	5
	22	16
	28	2

RS Cassiop.

	(−1	19)
July	3	8
	9	15
	15	22
	22	6
	28	13
Aug.	3	20
	10	3
	16	10
	22	17
	29	00

RY Cassiop.

	(−7	10)
July	7	5
	19	8
	31	12
Aug.	12	15
	24	18

Approximate Magnitudes of Variable Stars on May 1, 1910.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	h	R. A. 1900. m	Decl. 1900. °	′	Magn.	Name.	h	R.A. 1900. m	Decl. 1900. °	′	Magn
χ Androm.	0	10.8	+46	27	13.0 *i*	W Cassiop.		49.0	+58	1	11.0 *i*
T Androm.		17.2	+26	26	11 *i*	U Androm.	1	9.8	+40	11	9.0*d*
T Cassiop.		17.8	+55	14	8.5	S Cassiop.		12.3	+72	5	9.3*d*
R Androm.		18.8	+38	1	13.0*d*	RU Androm.		32.8	+38	10	14.0
Y Cephei		31.3	+79	48	13.0	Y Androm.		33.7	+38	50	10.9
U Cassiop.		40.8	+47	43	<15	U Persei		53.0	+54	20	10.6*d*
V Androm.		44.6	+35	6	9.0 *i*	W Androm.	2	11.2	+43	50	13.8*d*
RR Androm.		45.9	+33	50	9.8 *i*	Z Cephei		12.8	+81	13	13.5*d*
RV Cassiop.		47.1	+46	53	8.5 *i*	S Persei		15.7	+58	8	9.0 *i*

Approximate Magnitudes of Variable Stars on May 1, 1910—Con.

Name.	R. A. 1900.	Decl. 1900.	Magn.	Name.	R. A 1900	Decl. 1900	Magn.
	h m	° ′			h m	° ′	
RR Persei	2 21.7	+50 49	9.0	W Cancri	9 4.0	+25 39	11.3*d*
RR Cephei	30.4	+80 42	14.0	X Hydrae	30.7	−14 15	9.3 *i*
R Trianguli	31.0	+33 50	6.3 *i*	Y Draconis	31.1	+78 18	9.0
W Persei	43.2	+56 34	8.6	R Leo. Min.	39.6	+34 58	11.6*d*
Y Persei	3 20.9	+43 50	8.4	RR Hydrae	40.4	−23 34	<14
R Persei	23.7	+35 20	13.5	R Leonis	42.2	+11 54	9.5 *i*
T Tauri	4 16.2	+19 18	10.5 *i*	Y Hydrae	46.4	−22 33	8.6*d*
W Tauri	22.2	+15 49	8.8 *i*	V Leonis	54.5	+21 44	13.5*d*
R Tauri	22.8	+ 9 56	10.0*d*	R Urs. Maj.	10 37.6	+69 18	8.0
S Tauri	23.7	+ 9 44	9.0 *i*	V Hydrae	46.8	−20 43	7.3 *i*
T Camelop.	30.4	+65 57	8.3*d*	W Leonis	48.4	−14 15	13.5
X Camelop.	32.6	+74 56	9.0 *i*	S Leonis	11 5.7	+ 6 0	12.0*d*
V Tauri	46.2	+17 22	9.5 *i*	R Comae Ber.	59.1	+19 20	<13
R Orionis	53.6	+ 7 59	11.0*d*	T Virginis	12 9.5	− 5 29	12.5 *i*
R Leporis	55.0	−14 57	8.5*d*	R Corvi	14.4	−18 42	9.1*d*
V Orionis	5 0.8	+ 3 58	13.3*d*	SS Virginis	20.1	+ 1 19	7.0
T Leporis	0.6	−22 2	12.0*d*	T Can. Ven.	25.2	+32 3	10.5
R Aurigae	9.2	+53 28	7.8 *i*	Y Virginis	28.7	− 3 52	13.0*d*
S Aurigae	20.5	+34 4	9.0	U Centauri	28.0	−54 6	8.5
W Aurigae	20.1	+36 49	9.5 *i*	T Urs. Maj.	31.8	+60 2	9.8*d*
S Orionis	24.1	− 4 46	10.0*d*	R Virginis	33.4	+ 7 32	10.3 *i*
T Orionis	30.9	− 5 32	10.0	RS Urs. Maj.	34.4	+59 2	9.0
S Camelop.	30.2	+68 45	8.9*d*	S Urs. Maj.	39.6	+61 38	10.2 *i*
RR Tauri	33.3	+26 19	11.7	RU Virginis	42.2	+ 4 42	12.5
U Aurigae	35.6	+31 59	12.5*d*	U Virginis	46.0	+ 6 6	12.2*d*
Z Tauri	46.7	+15 46	13.5*d*	RV Virginis	13 2.7	−12 38	<13.5
V Camelop.	49.4	+74 30	11.3 *i*	V Virginis	22.6	− 2 39	10.0*d*
U Orionis	49.9	+20 10	7.0 *i*	R Hydrae	24.2	−22 46	8.3*d*
Z Aurigae	53.6	+53 18	10.0	S Virginis	27.8	− 6 41	10.9*d*
X Aurigae	6 4.4	+50 15	12.3 *i*	T Urs.Min.	32.6	+73 56	13.0 *i*
V Aurigae	16.5	+47 45	10.0*d*	R Can. Ven.	44.6	+40 2	12.5*d*
V Monoc.	17.7	− 2 9	9.5 *i*	RR Viriginis	59.6	− 8 43	11.5 *i*
S Lyncis	35.9	+58 0	10.3*d*	Z Bootis	14 1.7	+13 59	<13.5
X Gemin.	40.7	+30 23	13.0*d*	Z Virginis	5.0	−12 50	12.7*d*
W Monoc.	47.5	− 7 2	12.0*d*	R Centauri	9.4	−59 27	8.5*d*
Y Monoc.	51.3	+11 22	9.6*d*	U Urs. Min.	15.1	+67 15	11.4 *i*
X Monoc.	52.4	− 8 56	7.7 *i*	S Bootis	19.5	+54 16	11.8 *i*
R Lyncis	53.0	+55 28	11.7*d*	V Bootis	25.7	+39 18	9.5
RS Gemin.	55.2	+30 40	12.2*d*	R Camelop.	25.1	+84 17	9.3 *i*
V Can. Min.	7 1.5	+ 9 2	<16	R Bootis	32.8	+27 10	8.5 *i*
R Gemin.	1.3	+22 52	13.5*d*	V Librae	34.8	−17 14	9.0
R Can. Min.	3.2	+10 11	9.5*d*	U Bootis	49.7	+18 6	11.3*d*
RR Monoc.	12.4	+ 1 17	<14	RT Librae	15 0.8	−18 21	12.0*d*
V Gemin.	17.6	+13 17	7.5 *i*	Y Librae	6.4	− 5 38	11.5*d*
S Can. Min.	27.3	+ 8 32	9.1 *i*	S Librae	15.6	−20 2	10.5*d*
T Can. Min.	28.4	+11 58	<16	S Serpentis	17.0	+14 40	12.0 *i*
Z Puppis	28.3	−20 27	13.5*d*	S Coronae	17.3	+31 44	9.6*d*
U Can. Min.	35.9	+ 8 37	9.0 *i*	RS Librae	18.5	−22 33	7.5 *i*
S Gemin.	37.0	+23 41	13.7*d*	RU Librae	27.7	−14 59	9.5*d*
T Gemin.	43.3	+23 59	8.5*d*	S Urs.Min.	33.4	+78 58	7.7 *i*
U Puppis	56.1	−12 34	<15	X Librae	30.4	−20 50	12.0 *i*
R Cancri	8 11.0	+12 2	9.3 *i*	U Librae	36.2	−20 52	10.0
V Cancri	16.0	+17 36	9.3*d*	R Coronae	44.4	+28 28	9.8 *i*
RT Hydrae	24.7	− 5 59	8.3	X Coronae	45.2	+36 35	14.0*d*
U Cancri	30.0	+19 14	<14	R Serpentis	46.1	+15 26	7.0 *i*
X Urs. Maj.	33.7	+50 30	9.2 *i*	V Coronae	46.0	+39 52	10.0*d*
S Hydrae	48.4	+ 3 27	8.0 *i*	R Librae	47.9	−15 56	<15
T Hydrae	50.8	− 8 46	8.0 *i*	RR Librae	50.6	−18 1	9.0 *i*
T Cancri	51.0	+20 14	7.5 *i*	Z Coronae	52.2	+29 32	<14
S Pyxidis	9 0.7	−24 41	10.0 *i*	RZ Scorpii	58.6	−23 50	12.5*d*

Approximate Magnitudes of Variable Stars on May 1, 1910—Con.

Name.	R. A. 1900. h	m	Decl. 1900 °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
Z Scorpii	16	0.1	−21	28	12.0*d*	SV Herculis	18	22.3	+24	58	<13
R Herculis		1.7	+18	38	13.7*d*	RZ Herculis		32.7	+25	58	9.5 *i*
U Serpentis		2.5	+10	12	7.8	RT Lyrae		57.8	+37	22	13.8*d*
RU Herculis		6.0	+25	20	11.7*d*	R Aquilae	19	1.6	+ 8	5	11.5 *i*
U Herculis		21.4	+19	7	11.8 *i*	V Lyrae		5.2	+29	30	10.5 *i*
SS Herculis		28.0	+ 7	3	11.5*d*	R Cygni		34.9	+49	58	14.0
W Herculis		31.7	+37	32	9.5	RT Cygni		40.8	+48	32	12.0
R Draconis		32.4	+66	58	8.0*d*	TU Cygni		43.3	+48	49	12.0 *i*
S Herculis		47.4	+15	7	9.4 *i*	χ Cygni		46.7	+32	40	8.5 *i*
RT Herculis	17	6.8	+27	11	<14	Z Cygni		58.6	+49	46	10.0*d*
RS Herculis		17.5	+23	1	8.7 *i*	S Cygni	20	3.4	+57	42	<15
RU Ophiuchi		28.1	+ 9	30	9.8 *i*	X Cephei	21	3.6	+82	40	12.8*d*
RT Ophiuchi		51.8	+11	11	10.9*d*	T Cephei		8.2	+68	5	7.5 *i*
T Draconis		54.8	+58	14	12.5*d*	S Cephei		36.5	+78	10	9.2 *i*
RY Herculis		55.4	+19	29	13.0 *i*	S Lacertae	22	24.6	+39	48	8.5 *i*
T Herculis	18	5.3	+31	0	9.8*d*	R Lacertae		38.8	+41	51	10.5*d*
W Draconis		5.4	+65	56	10.5 *i*	Z Cassiop.	23	39.7	+56	2	14.0*d*
X Draconis		6.8	+66	8	14	RR Cassiop.		50.7	+53	8	13.0*d*
W Lyrae		11.5	+36	38	8.8	R Cassiop.		53.3	+50	50	9.4*d*

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled by Mr. Leon Campbell of the Harvard College Observatory from observations made at the Vassar, Mt. Holyoke, Olcott and Harvard Observatories, the latter including the South African Station.

COMMUNICATIONS QUESTIONS AND ANSWERS.

[This department is designed especially for the use of amateurs. Beginners are invited to send in their puzzling questions. The editors will try to see that answers are given to reasonable questions but will not hold themselves responsible for the correctness of the views expressed in the communications which may find place here. All communications should be brief.]

Amateur Astronomy at Toronto. Astronomical interest has witnessed a considerable revival here as well as elsewhere during recent times, and that quite apart from the interest which curiosity has awakened because of the return of Halley's Comet. Speaking of the comet for a moment, the newspapers as usual are sensational. Besides being threatened with extinction as we pass through the comet's tail in May, observers claim to be seeing it now in broad daylight, and with the naked eye. This morning I searched carefully for it north-east of Venus, but found that part of the sky brightened too rapidly to enable anything resembling a comet to be seen. Possibly next week better results may be had.

Recently I completed the re-figuring of my 15-inch reflector. Its performance on very bright stars is not quite satisfactory, but the manner in which it looks away into space and brings out the minute specks of light known as stars of the 11th, 12th, 13th magnitudes is wonderful. Castor is seen with three faint stars a long way out, the three forming the three corners of a close approach to a square. And Procyon, which disclosed in the 6-inch reflector no companions, shows, even amid the brightness of City lights, a whole host of companions, faint, but very visible. Stars are seen with faint companions

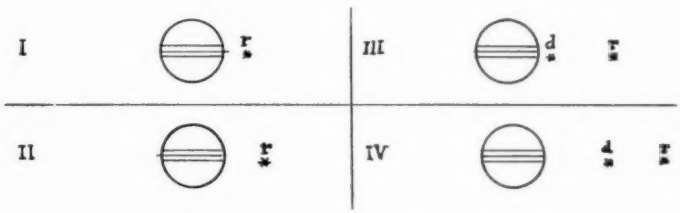
which never showed but as solitary before, some of the companions being close and some far off. Stars that one might almost dare to say have no business to have companions are there accompanied by other faintly shining specks of light. Praesepe with its frequently repeated triangular arrangements of stars shone so brilliantly that one might have thought the constellation was the Pleiades rent asunder and re-arranged. Jupiter is ringed from equator to poles, and looms up so brightly that one can almost observe its inhabitants tumbling over one another on their way to market. The Moon is wonderful, and when one looks at it first in the smaller 6-inch reflector near by, and then in the large instrument, the contrast is impressive. I have only powers up to 520 for the 15-inch, but so clearly cut is the Moon with that power that I sometimes fancy the instrument would stand nearly a million. As the Moon approaches the first quarter, and passes it, scarcely a night is there but someone telephones wishing to look at the sky and Moon. I also have a 12-inch reflector but the 15-inch is about as far superior to it, as it is to my first instrument made by myself, the 9½-inch reflector.

Our International Astronomical Society has many members, and nearly all of its members are using instruments of their own construction or are at work on them. Mr. Mellish has a 16-inch and Mr. Prahl of Milwaukee has a 14-inch reflector, both made by their owners. Others throughout Canada and the United States are similarly equipped. Mr. Wallace of Toronto, an old friend of mine whose days are spent in contracting, as mine are spent in practicing law, gives many spare hours to astronomical pursuits, and is experimenting in the making of Gregorian and dialyte telescopes, and is achieving success.

ALBERT R. J. F. HASSARD, B. C. L., Barrister etc.
9 North St., Toronto, Canada.
April 13, 1910.

QUESTION 1. What is the significance of the asterisk *, and the letters *d* and *r*, which one finds in the diagrams of the *Nautical Almanac* under the heading "Phases of the eclipses of the Satellites of Jupiter for an Inverting Telescope? For example we have in the *Ephemeris* and *Almanac* of 1908, page 495, Washington Meantime, March.

PHASES OF ECLIPSES OF THE SATELLITES FOR AN INVERTING TELESCOPE



ANSWER TO QUESTION 1. The asterisk denotes the position of the satellite at its disappearance in or reappearance from eclipse as denoted by *d* and *r*. It must be noted here that the eclipse is the passage of the satellite through Jupiter's shadow and not the disappearance behind the planets disk. Such a disappearance is an occultation, not an eclipse. It is readily seen then that when the angular distance of Jupiter from the Sun is large, the shadow cast

by Jupiter will make a large angle with the line of sight between that planet and the Earth and consequently that the disappearance of a Satellite in and its reappearance from the shadow can be noted by an observer on the Earth

QUESTION 2. What are the names of the stars forming the cluster to which our Sun is supposed to belong?

ANSWER TO QUESTION 2. For the answer to this question we are indebted to Professor Lewis Boss of the Dudley Observatory Albany, N. Y., who for many years has been investigating the motions of the brighter stars. Professor Boss says: "I am not aware that there is a "sun cluster." There may have been speculations to that effect (I may have speculated somewhere myself); but these surmises are wholly too vague, so far as my knowledge extends, to warrant any serious treatment."

QUESTION 3. Well informed amateurs know that the shifting of the Fraunhofer lines toward the red end of the spectrum indicates that a star is approaching us and if shifted toward the violet end, the indication is that the star is receding from us. Just how is the number of miles of approach or recession determined?

GENERAL NOTES.

With this number of POPULAR ASTRONOMY the new management assumes control of the magazine. Our aim will be to make the paper true to its name, a popular magazine, useful alike to amateur and professional astronomers. To this end the coöperation of all our readers is earnestly solicited. We invite friendly criticisms and suggestions of ways in which the paper may be improved.

Professor W. W. Payne, who retires from the management, deserves a great deal of credit for what he has done in the way of popularizing astronomy and for his success in making a magazine, which from its nature could appeal only to a limited number of readers, pay for itself. What this has meant in the way of obstacles overcome and hard nerve-racking work, done while he was carrying on his regular duties as a College Professor, very few of the readers can realize. It is our hope that we may not allow the magazine to in any way fall below the standard which he set for it.

No immediate change will be made in the form and plan of the publication, except that with this number we begin a new department entitled "Communications, Questions and Answers," of which we hope amateurs will make free use. Popular interest in astronomy has greatly increased during the past few months and we hope that this interest will not die out with the waning of Halley's comet.

Remember that the next number of POPULAR ASTRONOMY will not appear until August.

The Planet Mars.—The following communication from Mr. C.D. Perrine formerly of Lick Observatory now Director of the National Observatory of Argentine Republic, South America, is given in *Science* for April 29, 1910:

"I should very much like to urge the importance of the suggestion made by Professor R. G. Aitken in the issue of *Science* for January 21, 1910 that Mr. Percival Lowell invite a committee of *recognized experts* in planetary observation, to go to Flagstaff and with him to observe the planet Mars (and if possible Venus and Mercury also.)

"I find here in South America just as keen an interest by the public in the real state of our knowledge of Mars, as anywhere in the world, and am sure that no greater service could be rendered to astronomical science from the standpoint of the intelligent public, than to settle some of the many open questions relating to the surface markings of Mars.

"As Professor Aitken points out, doctors disagree in this matter and to such an extent that the average man knows not what to believe, he sees so many contradictory statements, drawings and photographs.

"It need hardly be pointed out that little real progress can be made in any branch of scientific work until the fundamental points are placed on a much more secure foundation than are many of the most important details regarding Mars.

"It would seem that the best way of finally setting some of these matters would be as suggested by Professor Aitken, to have them passed upon by a committee of experts of such well-recognized standing as to make their unanimous verdict final and acceptable to all scientific men.

"Then and not until then, will these questions of the surface markings of Mars be upon a dependable basis.

"It is also pertinent to point out the saving of time which will result in many ways and to many people by having a sure foundation in this matter. The financing of such a project should not be at all difficult considering the general interest which attaches to Mars."

A Valuable Library for Sale.—The library of Dr. Egon Ritter von Oppolzer, late Professor of Astronomy in the University of Innsbruck, is for sale. This library contains about 2000 volumes and pamphlets on astronomy and allied subjects, and is especially complete as regards works on logarithms. This is a good opportunity for some new observatory to obtain an astronomical library already selected. Anyone desiring to purchase may address Dr. Johann R. von Oppolzer, Vienna, VIII, Alserstrasse 25, Austria.

Writings of Sir William Herschel. Professor T. J. J. See, Director of the Naval Observatory at Mare Island, California, has purchased from Wm. Wesley & Son, the well known booksellers of London, a complete set of the writings of Sir William Herschel, extracted from the Philosophical Transactions, 1780-1818. They include 70 papers, and make up three large quarto volumes. These important papers are now extremely rare, and so inaccessible to the modern reader that a joint committee has been formed of members of the Royal Society and Royal Astronomical Society to consider the republication of the whole of Herschel's works. England owes this honor to the most illustrious of modern astronomers.

Descriptive Meteorology—by Professor Willis L. Moore, Chief of the United States Weather Bureau, is a comprehensive introduction to modern meteorology. It is largely devoid of technical terms and effort was made to discuss the subject under consideration so as to leave the reader with clear and correct ideas without the use of mathematics. Among the important features in the book are the discussions of the relative proportions of the important gases of the atmosphere, of indirect illumination due to dust particles in the air, of cyclones and anticyclones, of the vertical distribution of temperature during different seasons and under different weather conditions and of precipitation. The chapter on weather forcasting should be especially valuable to the layman. The volume is published by D. Appleton & Co.

Chats on Astronomy, by H. P. Hollis, President of the British Astronomical Association. Publisher; J. B. Lippincott Company, Philadelphia.

This little book, as the author says in his preface, has not been written for astronomers, but there are many persons who ask questions of this type:—"Is Venus bright once a year?" "Does the Moon always shine in an east window in the evening as the Sun does in the morning?" "Will it do me harm if the Moon shines on my bed when I am asleep? You ought to know because you are an astronomer." To answer some such questions as these, and to give a little information about a much misunderstood occupation the author gives as sufficient excuse for writing a very entertaining book of 221 pages. It is up to date, the frontispiece being a reproduction of a photograph of Halley's comet taken last September. The following sentences about Halley's comet are *apropos* at the present time: "So far as the prediction and the discovery of the comet are concerned, success has been complete, but as a popular spectacle there seems little doubt but that Halley's comet at this return will be a failure. It might have happened to have come back at a time of year when it would have been seen at its brightest when in the midnight sky. As a matter of fact, it will be at its brightest when it and the Sun are on the same side of the Earth, and its glories to the general public will be lost in the twilight."

In the High Heavens. A copy of the new edition of Sir Robert S. Ball's book, "In the High Heavens" has been received. The book is published by Sir Isaac Pitman & Sons, Ltd, London, and may be obtained from J. B. Lippincott Company, Philadelphia. It has been revised and somewhat enlarged by the author. It now contains an exposition of many of the branches of Astronomy to which much attention has been directed in recent years. The results of long and difficult researches are set forth in an interesting manner, and in such a way that one who is not familiar with the mathematical processes involved in these researches may understand the results. The book contains forty-four illustrations which serve to make clear to the reader the matter discussed.

A number of pages is devoted to the motions of the so-called fixed stars, and it is shown that in the course of half a million years the appearance of the heavens is sensibly altered.

In answer to the question, "Is the Universe Infinite," the author argues from the theory of probabilities that the number of visible stars is doubtless much smaller than the number of dark bodies. Yet he shows that the famous axiom of Euclid concerning parallel lines is really not an axiom, and a space in which that axiom is not true is not necessarily infinite. Hence the conclusion that the Universe is infinite is not a mathematical necessity.

The question as to how long the Earth can sustain life is discussed in a very thorough manner. The most probable source of the Sun's heat is given to be the contraction of the Sun, which is considered as practically entirely gaseous. Helmholtz has shown that when a gaseous body loses heat by radiation the contraction is sufficient to increase the temperature in the body of reduced size. Such is the condition in the Sun. Hence the temperature of the Sun would be increasing while the quantity of heat it contains is really decreasing. The Sun seems to have spent four-fifths of his energy and hence will not be able to give out heat at the present rate for more than four or five million years. That period is then the limit of the existence of life on the planet. Later the Sun may again, by collision with some other body, acquire a new supply of heat, and again create favorable conditions for life on our planet.

Other chapters are concerned with The Fifth Satellite of Jupiter, Mars, Spectroscopic Astronomy, Solar Eclipse, and the Origin of Meteorites.